DEVELOPING AND TESTING AN INNOVATIVE ARCHITECTURAL PROGRAMMING SIMULATION AS A PRECURSOR TO TARGET VALUE DESIGN

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE.

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Major Subject: Construction Management.

ABSTRACT

More than half of international construction projects are underperforming. Project success has been correlated with two key factors including managing cost to achieve efficiencies and creating and improving values. Cost overruns remained ubiquitous. Many factors and reasons were identified for construction project cost overruns. Poorly defined scope of work ranked as the one of the highest reasons for poor performance over which owners and construction stakeholders have control. An owner's requirements and expectations are specified during the programming phase of a project and these define a design's scope of work.

One main focus of Target Value Design (TVD) is making owners' value a primary driver of design by improving project definition during programming — thus optimizing the design phase. While recently the number of published research praising TVD has been increasing, there is a lack of information regarding the application of architectural programming of a project to TVD. The purpose of this research is to report on a study aiming to develop and test a lean game designed by the author of this research, to outline the importance of architectural programming and its effects on construction projects. This simulation was tested at Texas A&M University. The author described findings from testing an innovative lean game and administrating to participants a post-game questionnaire. Preliminary results suggest that this lean simulation appears valid for conveying the necessity of including systematic architectural programming at the start of building cost design exercises such as TVD. Ultimately, the simulation can be further improved based on collected feedback from participants.

DEDICATION

I would like to dedicate this work to my parents Mr. Hadi Solhjou Khah and Mrs. Kimia Molavi whose dreams for me have resulted in this achievement and without their loving upbringing and nurturing; I would not have been where I am today and what I am today. Had it not been for my parents' unflinching insistence and support, my dreams of excelling in education would have remained mere dreams.

ACKNOWLEDGEMENTS

In my journey towards this degree, I have found a teacher, an inspiration, a role model and a pillar of support in my Guide, Dr. Zofia Rybkowski. She has been there providing her heartfelt support and guidance at all times and has given me invaluable guidance, inspiration and suggestions in my quest for knowledge. She has given me all the freedom to pursue my research, while silently and non-obtrusively ensuring that I stay on course and do not deviate from the core of my research. Without her able guidance, this thesis would not have been possible and I shall be eternally grateful to her for her assistance.

Thank you Dr. Pentecost, Dr. Choudhury, Dr. Behzadan for agreeing to serve on my committee.

I would like to thank my friend Daniel L. Hirsch for helping develop the Architectural Programming Lean Simulation.

Finally, I would like to acknowledge and thank the Department of Construction Science at Texas A&M University for allowing me to conduct my research and providing any assistance requested.

CONTRIBUTORS AND FUNDING SOURCES

This work was supervised by a thesis committee consisting of Dr. Zofia Rybkowski, Dr. Ray Pentecost of the Department of Architecture, Dr. Amir Behzadan, and Dr. Iftekharuddin Choudhury of Department of Construction Science.

All work for the thesis was completed independently by the student, and no outside funding was received for the research and compilation of this document.

NOMENCLATURE

AEC	Architecture, Engineering, and Construction
AP	Architectural Programming
ARCH	Architecture
BA	Business Administration
COSC	Construction Science
CVEN	Civil Engineering
DWG	Drawing
FY	Fiscal Year
OAEC	Owner, Architect, Engineer, Contractors
TAMU	Texas A&M University
TC	Target Costing
TVD	Target Value Design
Q & A	Question and Answer
RND	Round
SF	Square Foot

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1. INTRODUCTION

Venkataraman and Pinto (2011) discussed that managing costs to achieve efficiencies, and creating and developing value are pivotal characteristics of project success. Based on a report provided by KPMG, fifty-three percent (53%) of overall construction projects were underperforming in the fiscal year (FY) of 2014 (Figure 1[1]).

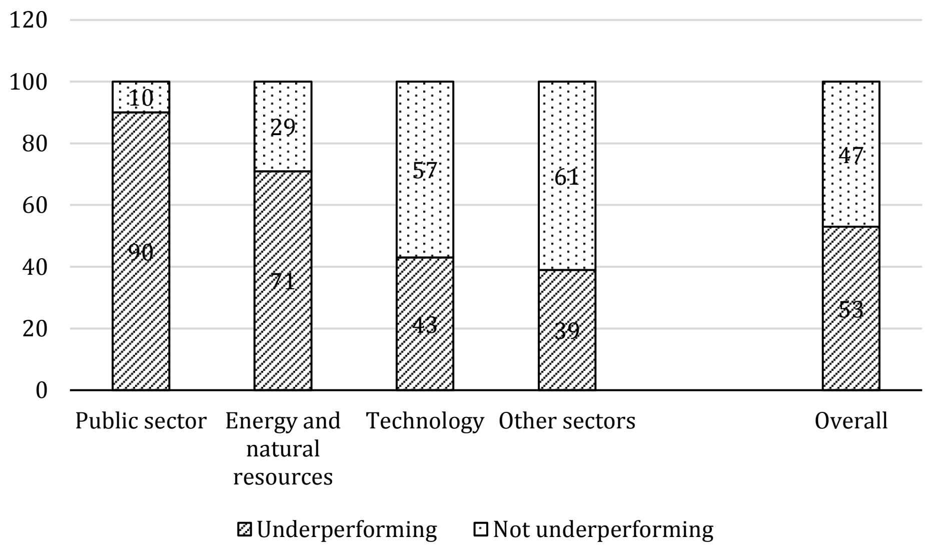

Figure 1: Percentage of construction projects underpeforming in FY 2014, by sector, Adapted from: KPMG 2015

For successful project delivery, estimating accurate costs are crucial. Many techniques have been developed for the purpose of evaluating the possibility of project cost overruns and structuring procedures to reduce this possibility (Attala and Hegazy 2003; Bhargava et al. 2010; Birnie and Yates 1991; Flyvbjerg 2008; Jahren and Ashe 1990; Love et al. 2012). Cost overruns are widespread in spite of implementing such techniques and utilizing contemporary organizational and managerial practices (Bhargava et al. 2010; Hester et al. 1991; Ibbs and Allen

[1] The data is based on interviews with 109 respondents; senior leaders working in the construction industry.

1995; Love 2002). Table 1 represents international projects which have encountered cost overruns.

Table 1: Catastrophically Over-Budget International Construction Projects, Adapted from Podio.com

Project	Country	Over Budget Percentage	Completion Year
Montreal Olympic Stadium	Canada	1990%	1976
Sydney Opera House	Australia	1357%	1973
Scottish Parliament Building	UK	935%	2004
Boston's Big Dig	USA	421%	2007
Budapest Metro Line 4	Hungary	353%	2014
Sochi Olympics	Russia	325%	2014
Compostela City of Culture	Spain	270%	2011
London Olympics	UK	265%	2011
The Shard	UK	243%	2012
Brazil World Cup Stadiums	Brazil	227%	2014
International Space Station	Various	186%	2011
Edinburg Trams	UK	167%	2014
Denver International	USA	164%	1995
The Gorges Dam	China	163%	2006
The Channel Tunnel	UK	145%	1994
Empire State Building	USA	100%	1931
Athens Olympics	Greece	95%	2004
Jubilee Line Extension	UK	84%	1999
Wembley Stadium	UK	81%	2007
Millennium Dome	UK	79%	1999
Leipzig City Tunnel	Germany	68%	2013
Great Belt Fixed Link	Denmark	54%	1998

Recently, notable budget and schedule overruns are deemed to be the norm rather than the exception (Venkataraman and Pinto 2011). Through a literature review the author of this research conducted, all the potential determinants of budget overrun were categorized into seven groups based on originating factors, namely project, contract, owner, contractor, consultant, labor and external. In the present day, a group of researchers had refined and categorized the factors into several groups based on causative factors of the cost overrun as tabulated in Table 2 (Karunakaran et al. 2018).

Table 2: Categorization of cost overrun factors by previous researchers, Adapted from Karunakaran et al. (2018)

Researchers	**Originating/Causative Factors**
Le-Hoai et al. (2008)	Owner, Consultant, Contractor, Material/ Labor, Project and External
Ameh et al. (2010)	Environmental, Construction, Construction Item, Cost Estimation and Financing
Aziz (2013)	Owner, Designer, Contractor, Project, and Material/Labor
Polat et al. (2014)	Contract, Time, Cost, Quality, Human Resource, Communicatios and Risk
Zewdu and Aregaw (2015)	Cost Estimation, Construction Item, Project Participant, Environmental, Financing
Derakhshanalavijeh and Teixeira (2017)	Owner, Consultant, Contractor, Project, Material/Labor
Niazi and Painting (2017)	Client, Contractor, Consultant, Labor, Material/Equipment, External

Causative factors are summarized in Figure 2, and compared the factors that have been the most frequently cited by previous researchers (Karunakaran et al. 2018).

Figure 2: Categorization of the cost overrun by originating factors according to literature shown in Table 2, Adapted from Karunakaran et al. (2018)

Owner, consultant, and contractor can be considered as the most contributive groups to construction project cost overruns. Generally, various stakeholders are involved in construction projects. Unifying stakeholders and their employees from various companies to work toward a shared goal is a considerable challenge in the construction industry. Recognized as a primary factor in reducing performance and efficiency of construction projects (Hansen and Vanegas 2003), poor control of the early design stages often results in lower quality of the constructed artefact (Ballard 2008; Hansen and Vanegas 2003; Tilley 2005). The aforementioned challenge in conjunction with chaotic design management approaches and various design practices increase the probability of design errors and conflicts (Tauriainen et al. 2016).

Rosenfled (2013) discussed fifteen (15) universal root causes (Table 3) for cost overruns in the construction industry via a cross-sectional survey of two-hundred (200) construction managers.

Table 3: The 15 universal root causes of construction-cost overruns, adapted from Rosenfled (2013)

Rank Order	**Cause**	**Percentage**
1	Premature tender documents (drawings, bill of quantities, specifications, contracts, and legal documents)	86.7
2	Too many changes in owners' requirements or definitions	71.3
3	Tender-winning prices are unrealistically low (suicide tendering)	65.1
4	Unclear, ambiguous, and contradicting terms in the tender documents	38.5
5	Insufficient, unstandardized owner's brief	35.9
6	Too small a design budget	32.3
7	Insufficient information about ground conditions	28.7
7[2]	Late start of the planning process, and with too low a budget	28.7
9	Shortage in high-quality management personnel	27.9
10	Unbalanced distribution of risk between owner and contractor	21.5
11	Culture of conflicts and lack of trust	17.9
12	Lack of standard requirements from designers and poorly enforced professional liability of designers	16.9
13	Unconstructable design	15.9
14	Unclear division of responsibilities and lack of clear requirements for professional management	8.2
15	Force majeure (strikes/weather/regulation changes/accidents, etc.)	5.1

[2] These two items had the same percentage from respondent surveys.

Additionally, Figure 3 represents reasons for construction project cost overruns worldwide. The pre-eminent reason known as “Material price escalation” refers to insecurity of an economy and inflation over which construction stakeholders have no control. However, poorly defined scope is ascribed to be the second most influential reason for cost overruns in the construction industry, but the first over which the OAEC stakeholder team has control.

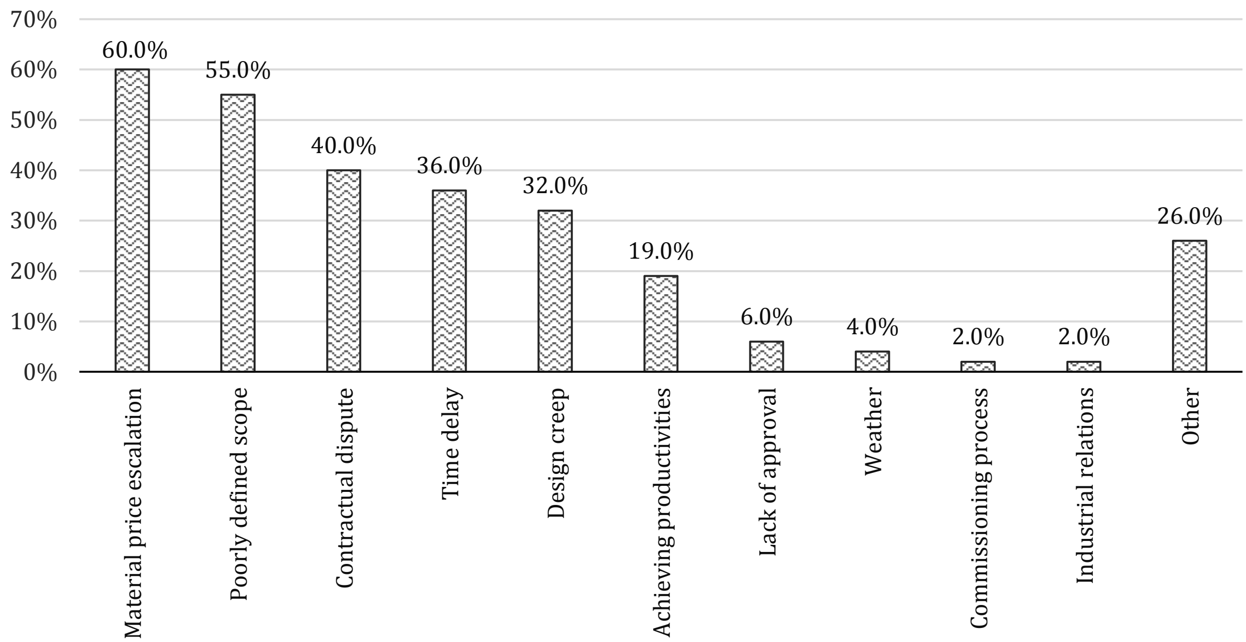

Figure 3: Reasons for cost overrun in construction projects worldwide, as of 2008, Adapted from PMI; KPMG

Defined as the research and decision-making process that identifies the scope of work to be designed (WDBG 2016), Architectural Programming (AP) has been cited as a poorly implemented phase in the construction industry (Morêda Neto et al. 2016). El. Reifi and Emmitt (2013) and Tilley (2005) discussed the role of inadequate management of the initial design phase results in document failure and rework. Macomber et al. (2008) stated that a project is initiated with requirements and expectations from the owner side; consequently, any changes in phases pertinent to the nature of that owner have the greatest effects on the project in terms of level of influence and cost of the project. Macomber et al. (2008) wrote that in order to decrease the probability of project failures, owners' expectations and requirements must be the focus of the design conversation.

The MacLeamy Curve (Figure 4[3]) shows that early design decisions in the process, lead to the greatest impacts on cost and functional capabilities of a project. Thus, the association of stakeholders in the early stages of a project is crucial (Morêda Neto 2016).

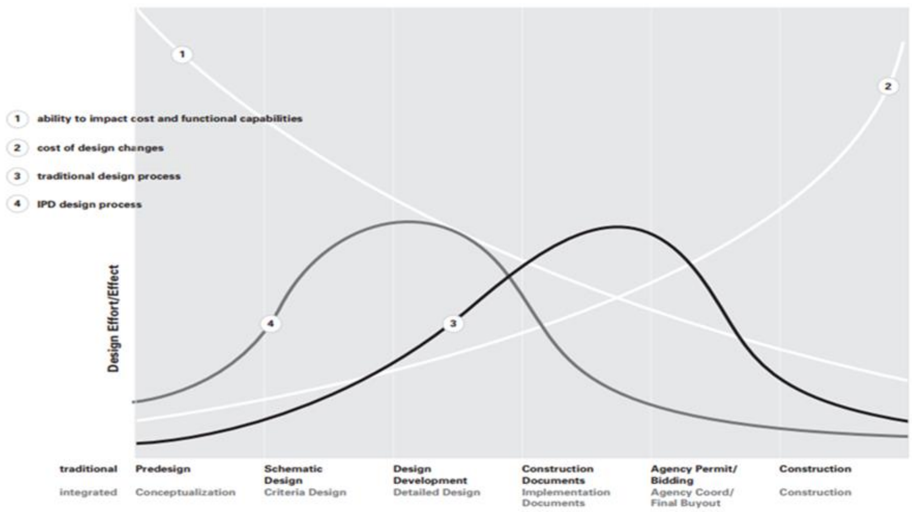

Figure 4: MacLeamy Curve, Reprinted from: Integrated Project Delivery: A Guide – Version 1, 2007 (p.21)

It has been demonstrated that a poorly executed architectural programming phase, late engagement of disciplines and insufficient communication among different parties adversely affect construction projects as a whole (Morêda Neto 2016). Moreover, owner s' expectations and building efficiency are individualistic and to some extent fuzzy in themselves (CIB-W60 1999, Takeda), Thus misunderstanding owners' values, requirements, and expectations leads to negatively affecting the building value in the matter of not obtaining what owners required and expected (Thyssen et al. 2010).

[3] *Reprinted with permission from "Integrated Project Delivery: A Guide – Version 1", by American Institute of Architects, 2007, AIA California Council, Sacramento, CA, Copyright 2007 by AIA|AIA CC

The purpose of Target Value Design (TVD) is to achieve better quality, reliability, and excellent life cycle performance, while staying within the budget. TVD demonstrates continuous design procedures, and their assessment in order to meet or exceed owners' value and expectations in addition to maintaining projects within or under their target cost (TC) (Pishdad-Bozorgi et al. 2013).

"Findings from a literature review of Target Costing (TC) and TVD have revealed a critical knowledge gap. In addition, applying TC and TVD in the construction industry is extremely complex, and there is still no formal consensus on this subject" (p.64) (Morêda Neto 2016). In other words, there are opportunities to explore approaches to applying architectural programming of a project to TVD, which is the main motivation for this research.

2. REVIEW OF LITERATURE

2.1 Target Value Design

"Target Value Design (TVD) is a management strategy and known as a complex system, including: Project definition (A), Design (B), and Construction stages (C) (Figure 5[4]). It correlates closely with Lean thinking in design and construction" (p. 2) (Zimina et al. 2012). Planning to achieve better quality, reliability, and excellent life cycle performance, while staying within the budget of the project, TVD is a practice intending to adjust a project's design and cost and aligning owners' values so the design can meet to cost (Lee et al. 2012). Furthermore, TVD attempts to define the design process as well as its evaluation to achieve the value sought by the owner while satisfying target cost constraints for the project (Pishdad-Bozorgi et al. 2013).

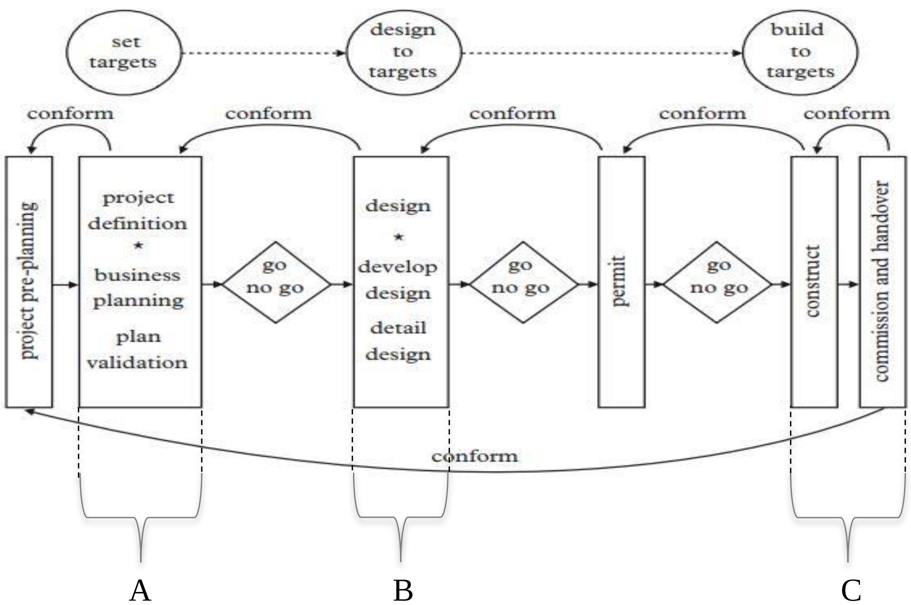

Figure 5: Target Value Design process scheme, (Figure 4 in Zimina et al. 2012)

[4] *Reprinted with permission from "Target value design: using collaboration and a lean approach to reduce construction cost." by Zimina, D., Ballard, G., and Pasquire, C., 2012, Construction Management and Economics, 30(5), 383-398, Copyright 2012 by Taylor & Francis.

Ballard and Rybkowski (2009) argued that first cost is more achievable when architects utilize TVD during the design process (Ballard and Reiser 2004; Macomber et al. 2008; Nicolini et al. 2000). TVD depends on some primary elements (Table 4), while targets in TVD help to accommodate these elements and improve project scope definitions.

Table 4: TVD Benchmark, Adapted from Ballard (2011)

Element	Description
1	With service providers, the customer develops and evaluates the project business case.
2	The business case includes specification of an allowable cost. Financial constraints and limitations are specified.
3	The feasibility study involves all key stakeholders.
4	Feasibility is assessed through aligning ends, means and constraints.
5	The feasibility study produces a detailed budget and schedule aligned with scope and quality.
6	The owner is an active and permanent member of the project delivery team.
7	All team members understand the business case and stakeholder values.
8	Some form of relational contract is used to align the interests.
9	Cost and schedule targets cannot be exceeded, and only the customer can change target scope, quality, cost or Schedule.
10	Team members discuss about the cost, schedule and quality implications of design alternatives.
11	Cost estimating and budgeting are done continuously through intimate collaboration.
12	The Last Planner® system is used to coordinate the actions of team members.
13	Targets are set as stretch goals to spur innovation.
14	Target scope and cost are allocated to cross-functional TVD teams.
15	TVD teams update their cost estimates and basis of estimate (scope) frequently.
16	The project cost estimate is updated frequently to reflect TVD team updates.
17	Co-location is strongly advised.

According to Zimina et al. (2012) Target Costing (TC) – as opposed to TVD – is already utilized in frequent construction cost and project management practices. TVD mainly focuses on values that owners associate with the design, and accomplishes this by enhancing the project definition during architectural programming which optimizes the design phase (Morêda Neto 2016). Fundamental application of Target Value Design has resulted in an average fifteen percent (15%) reduction on the final cost in comparison to the market cost. Essential characteristics of TVD include: allowing flow of money across multiple stakeholders to identify the optimal investment for a project, concurrent application of all suitable design principles to the generation, and assessment and selection from output and procedure design options (Zimina et al. 2012).

2.2 Architectural Programming

The general perception of facility programming is that it is an information processing system intended to accommodate needs, expectations, and requirements of the user, owner, the designer, or the developer (Sanoff 2016). Growing owner expectations on project performance can contribute to the elaboration of owner requirements, and this demands an efficient approach (Yu and Shen 2013). The architectural programming process is crucial to delivering efficient construction projects. Deficiencies in buildings are often the outcome of a defective programming process. For this study, seven architectural programming methods were identified:

- Davis’s Programming;
- Farbestian’s Programming;
- McLaughlin’s Programming;
- Kurtz’s Programming;
- Moleski’s Programming;
- White’s Programming; and
- Peña’s Programming (Sanoff 1992).

Architectural planning is not a strictly defined process, because it depends on a programmer’s unique style and emphasis (Sanoff 1992; Sanoff 2016). Additionally, each model can be adapted to meet many types of owner needs. In the following section, each method of programming has been described in graphic diagrams.

2.2.1 Davis's Programming

The Davis's Programming method focuses on the planning of corporate facilities. It starts with programming (Davis and Szigeti 1979) and continues to an assessment of the facility during its operation. It contains 21 steps (Figure 6[5]) which include collecting information on "the operating facilities; on physiological needs; and on behavioral requirements" (p.3) (Sanoff 2016).

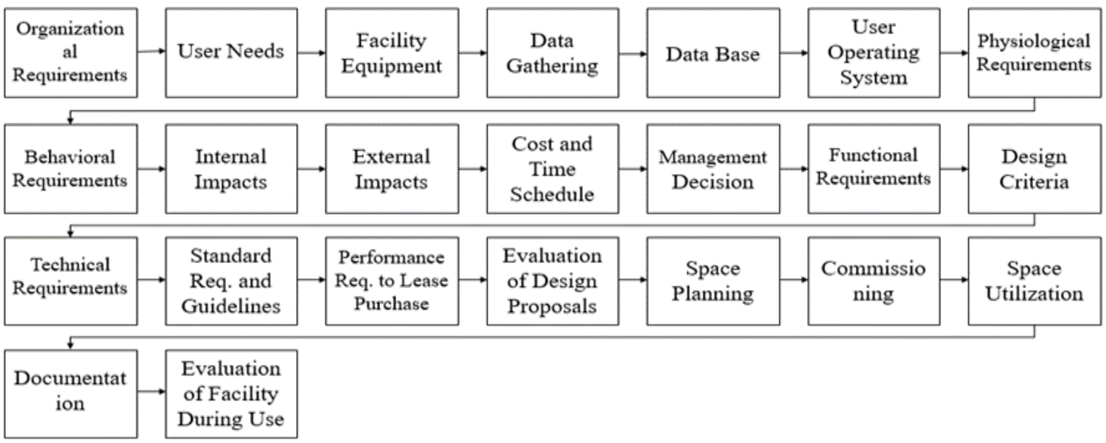

Figure 6: Davis's programming process, (Figure 1.1 in Sanoff 1992)

2.2.2 Farbstein's Programming

According to Palmer (1981), the Farbstein's programming method identifies owner needs at five main levels (Figure 7[6]). "After the owner reviews the performance criteria, the design issues and program options are identified for each issue. Each option is measured in terms of costs, benefits, and trade-offs" (p.4) (Sanoff 2016).

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[6] *Reprinted with permission from Integrating Programming, Evaluation and Participation in Design: A Theory Z approach, by Henry Sanoff, 1992, Aldershot, England, Copyright 1992 by Aldershot.

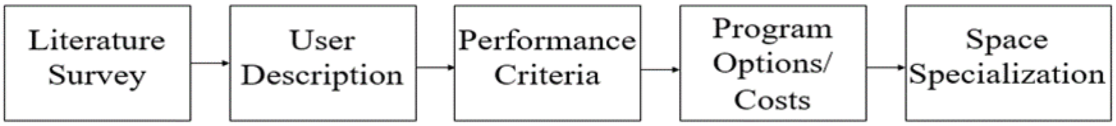

Figure 7: Farbestian's Programming Process, (Figure 1.2 in Sanoff 1992)

2.2.3 McLaughlin's Programming

The McLaughlin's programming method comprises three main stages (Figure 8[7]) based on "financial feasibility of the project, functional analysis, and project development" (p.4) (Sanoff 2016).

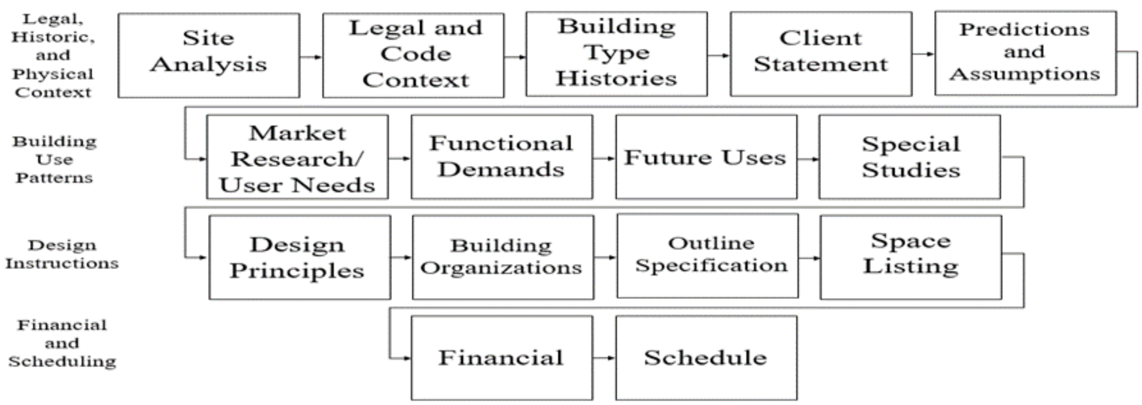

Figure 8: McLaughlin's Programming Process, (Figure 1.3 in Sanoff 1992)

2.2.4 Kurtz's Programming

The Kurtz's programming model focuses on continual programming lasting into the design phase. Kurtz afforms that "generalized long-range programmatic decisions should be made at the

[7] *Reprinted with permission from Integrating Programming, Evaluation and Participation in Design: A Theory Z approach, by Henry Sanoff, 1992, Aldershot, England, Copyright 1992 by Aldershot.

design stage of a project" (p.5) (Sanoff 2016). This programming method is depicted in Figure 9[8].

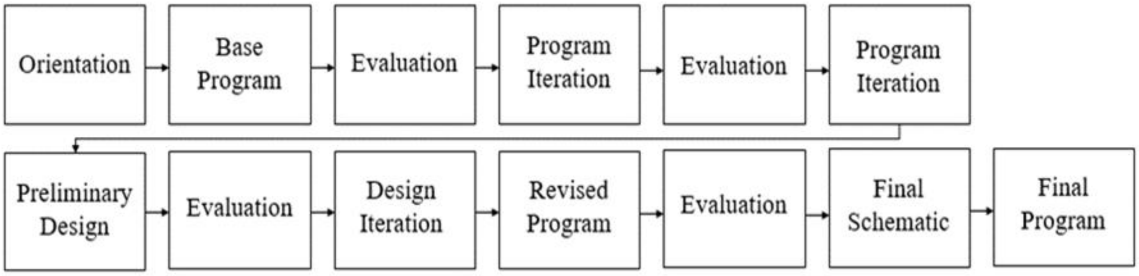

Figure 9: Kurtz's Programming Process, (Figure 1.4 in Sanoff 1992)

2.2.5 Moleski's Programming

Moleski's approach (Palmer 1981) consists of four stages and two intermediate reviews of the project with the owner, the architect, and the programmer (Figure 10[9]) (Sanoff 2016).

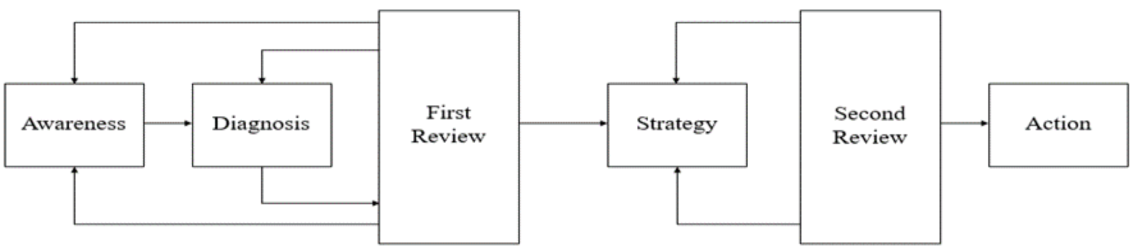

Figure 10: Moleski's Programming Process, (Figure 1.5 in Sanoff 1992)

2.2.6 White's Programming

The White's programming model consists of a series of tasks (Figure 11) divided into three phases: Pre-programming, Programming, Post-programming (Sanoff 1992).

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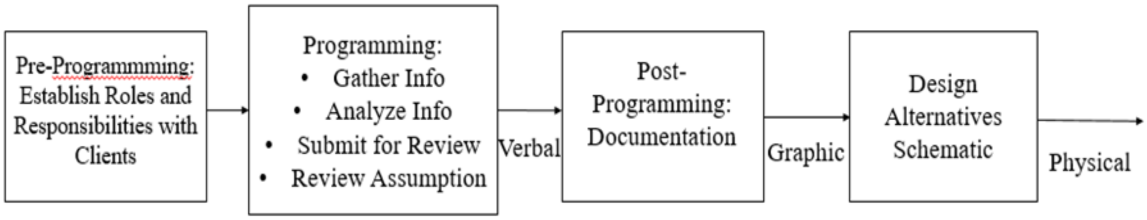

Figure 11: White's Programming Process, (Figure 1.7 in Sanoff 1992)

2.2.7 Peña's Programming

Peña's programming method encompasses four primary elements including: Function, Form, Economy, and Time (Figure 12). Including 132 considerations covering many aspects of a project, Peña's programming requires work sessions that gather all stakeholders involved in the project for a particular period of time (Sanoff 2016).

	Goals	**Facts**	**Concepts**	**Needs**	**Problesm Staement**
Function					
People Activities Relationship					
Form					
Site Environment Quality					
Economy					
Initial Budget Operating Costs Lifecycle Costs					
Time					
Past Present Future					

Figure 12: Peña's Programming Process, Adapted from Peña and Parshall (2012)

2.3 Lean Simulation

Training has been known as an influential attempt to develop trainees' proficiency, learning and attitude at the hand of learning experiences and engaging in effective activities (Garavan et al.1995; Reid et al. 1992). A literature review of training and development in the construction industry reveals there is poor investment in this area. The construction industry is required to develop pertinent training for its employees, thus helping them accelerate their learning (Bhatt 2016). Hassan et al. (2009) believes there is a vital need to study the performance "gaps" of employees and determine what they are required to learn; to accomplish this, training is fundamental.

In the construction industry, training and its advantages are underestimated, which leads to inadequate formal training activities (Kuykendall 2007). In a study conducted by Cox et al. (1998), it was found that companies with investigation in training practices increased their productivity by forty-two percent (42%). According to Figure 13, training, professional development, and continuing education are highly efficient ways to increase employee engagement. The study also demonstrated that trainees who continually improve their learning and obtain new skills experience more satisfaction and engagement when developing these new skills (Bhatt 2016).

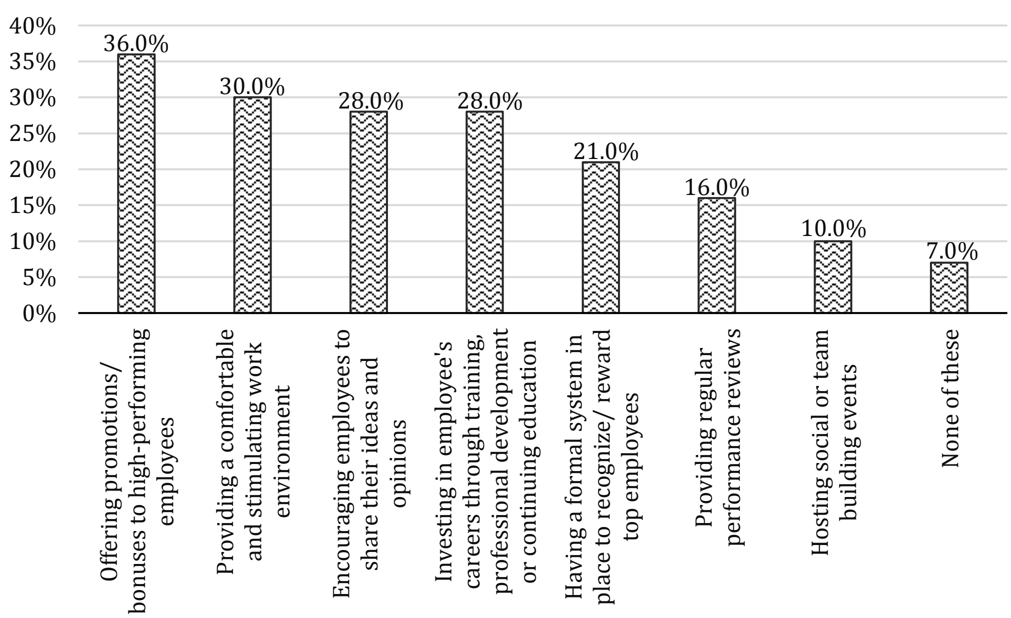

Figure 13: Effectiveness of Employees' Engagement Activity, Adapted from Bhatt (2016)

To help educate participants about TVD, Rybkowski et al. (2016) developed a two-phase estimating simulation to illustrate to participants the "Design/Develop Design/Detail Design" process (Figure 5, phase B) of TVD. However, "Project Definition/Business Planning/Plan Validation" (Figure 5, phase A) needs to proceed the design process as it informs designers of what an owner values. A simulation to introduce participants to phase A was needed and did not yet exist. Filling this gap was the basis for this thesis.

Lean training is applicable in many forms, including lectures, presentations, hands-on games and activities, videos, and case studies. These approaches are effective when used as a separate technique, but they can also be adopted together for better overall performance. Lean simulations are one of the most efficient methods to demonstrate the advantages of lean tools and concepts (Kuriger et al. 2010). Lean training is vital in establishing an advanced mindset and culture which is critical in a rewarding lean exercise. This training leads to the foundation for successful changes in an organization (Wan et al. 2008).

The Lean Construction Institution (LCI) recognizes Lean simulations as activities to deliver lean concepts (Verma 2003). According to Canizares (1997) and Walters et al. (1997), simulated games effectively assist students or trainees to understand real-world scenarios. Additionally, they ease the comprehension of lean concepts and their function in the construction industry.

The most substantial method of learning is the one which facilitates educators to observe something from another perspective (Kuhn 1970). Lean games offer a methodology to establish Lean thinking within a system (Friblick et al. 2007). The objective of Lean simulation games is to enable participants to practice lean methods and then assess their impacts on performance (de Carvalho et al. 2013). Successful Lean construction exercises facilitate a mindset conversion among individuals in the organizations aiming to implement Lean practices (Friblick et al. 2007). Furthermore, learning platforms such as Lean games encourages participants to voice their opinions and work through their concerns (Dewey 1933).

3. PROBLEM STATEMENT

This study seeks to address the need for construction stakeholders to develop an appreciation for systematic architectural programming at the start of a construction project during the early stages of Target Value Design (TVD). Although there are some research studies that have been devoted to TVD, the number of papers that document the application of architectural programming in a real-world projects is limited. The amount of information regarding the application of architectural programming to TVD is insufficient. However, because poorly defined scope has been demonstrated to be the largest controllable reason for project cost overruns worldwide, this research assumed that systematic architectural programming is currently insufficient. Additionally, in TVD, project definition is included as a separate upfront design step that should involve architectural programming. Thus far, there is no lean simulation to help OAEC stakeholders understand this critical upfront process. Therefore, the focus of this study is to design and test via proof of concept an innovative and functional Lean simulation in order to communicate the importance of architectural programming on value creation for the owner.

4. RESEARCH OBJECTIVES

The overall goal of this study is to develop and test a new lean simulation that conveys the importance of systematic architectural programming in determining value to a building owner at the start of Target Value Design. The objective of this specific research is to collect feedback after testing the simulation, and to use that feedback as a guide to improve future versions of the simulation.

5. RESEARCH QUESTIONS

The following questions helped guide this research.

- What do participants think about the purpose of this simulation?
- Do participants think the instructions were easy to understand?
- Do participants think this simulation is applicable to an actual project?
- How convincing was the game message to participants?
- What were the best parts of the game?
- What could be improved in the simulation?

6. PROPOSED METHODOLOGY

This paper documents exploratory and qualitative research, a literature review, development and testing a lean architectural programming simulation at Texas A&M University, and an evaluation of that simulation based on a questionnaire distributed to simulation participants. In this research, the author evaluated the importance of architectural programming (AP) by using an algorithmic manipulation of three floor plans to give a compilation of one-hundred-forty-four (144) possibilities. By conducting a subsequent evaluation, research tested how systematic architectural programming (AP) might benefit the OAEC industry, and whether it is important to play the simulation before embarking on Target Value Design (TVD).

The Architectural Programming lean simulation was designed to investigate perceptions about the importance of AP. It was designed and tested at the College of Architecture at Texas A&M University. It was pilot tested on graduate and undergraduate students, who were being prepared to enter the construction related industry within the next one to five years. Students were affiliated with the departments of Construction Science and Architecture, and Civil Engineering. The simulation received permission to be performed in the classrooms by the professors in the aforementioned departments at Texas A&M University, and exact dates and times were set to conduct the simulation in classes. To facilitate the simulation, the author read aloud instructions before playing. At various points she clarified aspects of the game as needed, based on verbal questions from the participants, and provided written questionnaires to secure feedback from the students following play.

6.1 Introduction

"Architectural Programming" is a lean simulation developed to mock up the pre-design architectural programming stage of a construction project.

6.2 Simulation Process

Before starting the game, instructions were presented orally by the facilitator. Participants were divided into groups of two members: one as an owner, and the other as an architect. Required material for this simulation included six (6) Architectural Programming Scenario which portrayed scenarios to define owners' expectations and requirements; Template for Scenarios; and two 11"*14" landscape format photocopies with one-hundred-forty-four (144) apartment layouts with different characteristics. Each plan was given an identifier and three assigned potential cost points per SF ($60, $150, and $300/SF). The purpose of this lean game is for architect players to identify owners' needs and then recommend to their owner partners' appropriate apartment plan layouts with associated costs per SF. The lean simulation was administrated in two rounds.

Round I:

Selected drawing numbers with associated cost per SF were written on slips of paper and shuffled in a bowl for owners to draw. Owners memorized the drawn plan identifier with costs, and the architect would need to guess the plan identifier with cost per SF. Architects were allowed to ask two yes or no questions pertinent to the given criteria on the blank "Template for Scenarios" in 4 minutes and owners would respond to their questions based on the given information in the related Scenarios. At the end of the first round the architects had to guess what they believed was the owners’ desired drawing number and its cost per SF. The facilitator then asked each architect to announce his or her guess.

The results of the guess were collected onto a drawn table onto the white board.

Round II:

In the second round, owners read their scenarios slowly to their architects. Architects were not allowed to ask any questions. But they were permitted to ask their owners to read their scenario again. With six (6) minutes time the architect players guessed on the drawing number and its cost per SF.

Participants’ guesses were again recorded on the table by the facilitator. The results for the two stages were compared to the impact of having more information and communication. At the end of the game, Peña’s Programming table was projected on a screen in order to demonstrate how the lessons of the game can be applied to actual projects.

In addition, a questionnaire was distributed to participants to collect feedback regarding their perceptions of the game.

6.3 Research Tool: Architectural Programming Simulation

6.3.1 Simulation overview

The researcher performed the simulation according to the rules mentioned in Appendix A. At each round, data reflecting architect players’ guesses were collected by game facilitator and wrote down on the board. Owners were asked to declare whether or not their team members’ guesses were correct. Note this was not done at the end of round one to ensure there would be no bias during the second round of play.

6.3.2 Objective of the simulation

This simulation is an effort to help the participants understand the importance of architectural programming in meeting owners' requirements and expectations. Moreover, this simulation indicates adverse effects of lack of communication between owners and architectural programmers on the outcomes of construction projects. To the best of author's knowledge, there is no previous lean simulation which explores the impact of architectural programming.

6.4 Data Analysis

The data collected on the white board tables for Architectural Programming Lean simulation was evaluated, as were the questionnaires completed by participants and all players respectively.

The white board table represented a compilation of information regarding drawing numbers and costs per SF at each round, correct guesses at each round of simulation, and improvement in architect players' guesses during round two since they were provided with more information.

Additionally, other factors such as gender ratios, age and experience of the participants, their educational departments, classification, and their major were documented. Details from the data analysis are discussed later in the Data Analysis and Findings and Discussion chapters.

7. RESEARCH LIMITATIONS AND ASSUMPTIONS

This research had some limitations, and assumptions namely:

- The sample size was relatively small (N=51); thus, the conclusions might not convincingly reflect the attributes of the real populations;
- It is limited to the context of the US construction industry and this research may not produce the same results outside the United States;
- The participants had enough insight and experience to test the simulation;
- Undergraduate and graduate students in the Departments of Construction Science and Architecture at Texas A&M University accurately represent future stakeholders of the construction industry. Their mindset is assumed to reflect the mindset of the industry; hence they were chosen for this research;
- It was assumed that students understood solar path differences between the northern and southern hemispheres; and
- The simulation does not consider the cultural differences among participants.

8. RESULTS AND DATA ANALYSIS

This chapter summarizes and analyzes results collected from "Architectural Programming" lean simulation participants. The simulation game was conducted with the graduate and undergraduate students in the departments of Construction Science and Architecture at Texas A&M University from September 17- 26, 2018. The simulation was modified with successive trials. Prototypes were tested on Construction Science (COSC) graduate students, and their feedback was reported into the final game. In the end, fifty-one (51) students were selected for testing a mature version of this simulation. Twenty-four (24) teams were formed with one (1) owner and one architect player per team, and one (1) team was formed with two (2) owners and one architect. The owners were responsible for providing architects with information in order to clarify expectations and requirements which they have.

Six scenarios and one-hundred-forty-four (144) apartment layouts were provided with five variables including:

1. Number of bedrooms;
2. Ability/Disability;
3. Solar Orientation;
4. Open vs. Closed Kitchen; and
5. Cost per SF.

Results from the Architectural Programming Lean experiment indicate there was a 850% increase in the number of corrects guesses. In other words, owners' requirements and expectations were not met during the first round but were largely met during the second round.

This increase consequently leads to about a seventy-seven percent (77.3%) decline in the number of incorrect guesses during the experiment's final round.

The simulation results are shown in Table 5-8, and outcomes are summarized in Table 9. Table 5 is a compilation of results from participants during the first class in which the game was conducted. Fifteen (15) participants were undergraduate students in the department of Construction Science (COSC) and one participant was an undergrad student and a business major. The owner player in the group 7 did not correctly follow instruction, so his results were eliminated from the study.

Table 5: Guess table for the first group of participants

RND 1	Team #															
	1		2		3		4		5		6		7		8	
Guessed DWG # and Price	A4-1 $150/SF		E3-1 $150/SF		E3-2 $150/SF		B3-2 $150/SF		D4-2 $150/SF		C2-1 $150/SF		D3-1 $150/SF		D3-2 $150/SF	
	Y	***N***	Y	***N***	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
RND 2																
Guessed DWG # and Price	E3-1 $300/SF		C4-1 $60/SF		A2-2 $150/SF		B3-2 $60/SF		D3-2 $300/SF		D3-1 $150/SF		D3-1 $150/SF		A1-2 $150/SF	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N

As indicated in Table 6, ten (10) groups participated in the Architectural Programming Lean game in the second class.

Table 6: Guess table for the second group of participants

RND 1	Team #																			
	1		2		3		4		5		6		7		8		9		10	
Guessed DWG # and Price	E2-1 $150/ SF		B2-2 $300/S F		C4-1 $150/S F		D1-2 $150/S F		D4-1 $150/S F		B2-2 $60/SF		E3-1 $300/S F		A1-2 $300/S F		C4-1 $150/S F		A1-2 $150/S F	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
RND 2																				
Guessed DWG # and Price	E3-1 $300/ SF		F3-2 $150/S F		C4-1 $60/SF		D4-2 $150/S F		D3-1 $150/S F		B3-2 $60/SF		E3-1 $300/S F		A2-2 $150/S F		C4-1 $60/SF		A2-2 $150/S F	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N

This simulation was tested for a third time with ten (10) participants in five (5) groups. Results are summarized in Table 7. All participants were graduate students of Architecture (ARCH).

Table 7: Guess table for the third group of participants

RND 1	Team #									
	1		2		3		4		5	
Guessed DWG # and Price	E1-2 $60/SF		D4-2 $150/SF		A4-2 $300/SF		D2-1 $150/SF		B4-1 $150/SF	
	Y	N	Y	N	Y	N	Y	N	Y	N
RND 2										
Guessed DWG # and Price	A2-2 $150/SF		D4-2 $150/SF		B3-2 $60/SF		C4-1 $60/SF		D4-1 $150/SF	
	Y	N	Y	N	Y	N	Y	N	Y	N

Lastly, five graduate participants participated in the study. Having background in Civil engineering (CVEN) and Construction Science (COSC), Architectural Programming simulation players were formed into two groups including one group of one owner and one architect, and one group of two owners and one architect. Their guesses and outcomes are shown in Table 8.

Table 8: Guess table for the fourth group of participants

RND 1	Team #			
	1		2	
Guessed DWG # and Price	E1-1	$60/SF	A1-2	$300/SF
	Y	N	Y	N
RND 2				
Guessed DWG # and Price	D4-1	$60/SF	D2-2	$150/SF
	Y	N	Y	N

Table 9 summarizes results of four (4) pilot tests from the Architectural Programming simulation. One team violated the instructions and its team players' guesses were eliminated from the study.

Table 9: Summarized pilot test results for Architectural Programming Lean Simulation

Round	Number of Correct Guesses	Number of Incorrect Guesses	Total Quantity
Round 1	2	22	24
Round 2	19	5	24
Overall	21	27	48

Figure 14 demonstrates the influence of comprehensive architectural programming (AP) on the final design which results in meeting owners' requirement. This figure is set up on the given data in Table 9.

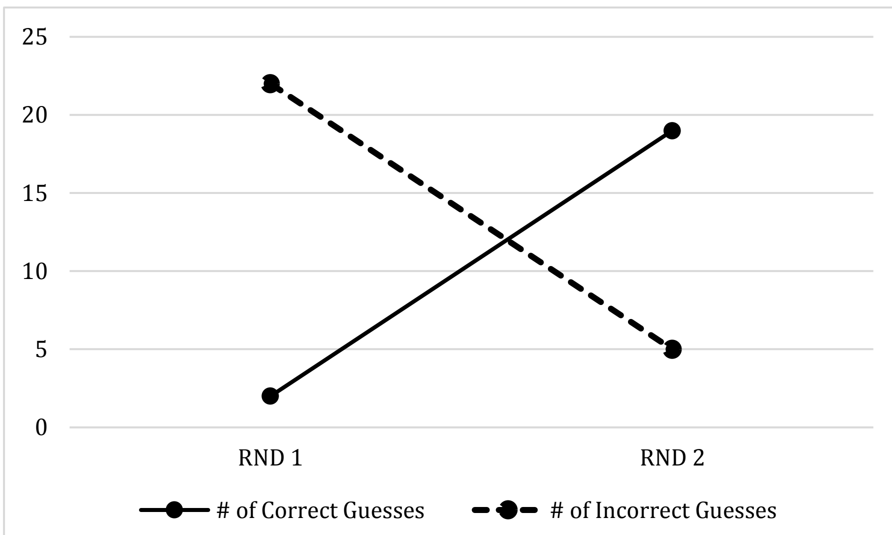

Figure 14: Impact Analysis of AP in Architectural Programming Lean Simulation Experiment Outcome

Various purposes for the Architectural Programming lean simulation experiment were identified by participants. Some of these goals are not totally separated from each other, and in some cases they can be interchangeable. As Figure 15 shows, approximately fifty-five percent (54.9%) of players believed that "Communication" is the primary purpose of the simulation. They clearly use the "Communication" term in their statements. Additionally, talking, asking more questions and answers, acquiring more information, which can be perceived as means of communication, were identified as purpose of this simulation. Moreover, “Identifying owners’ needs” ranked as the second goal for the simulation.

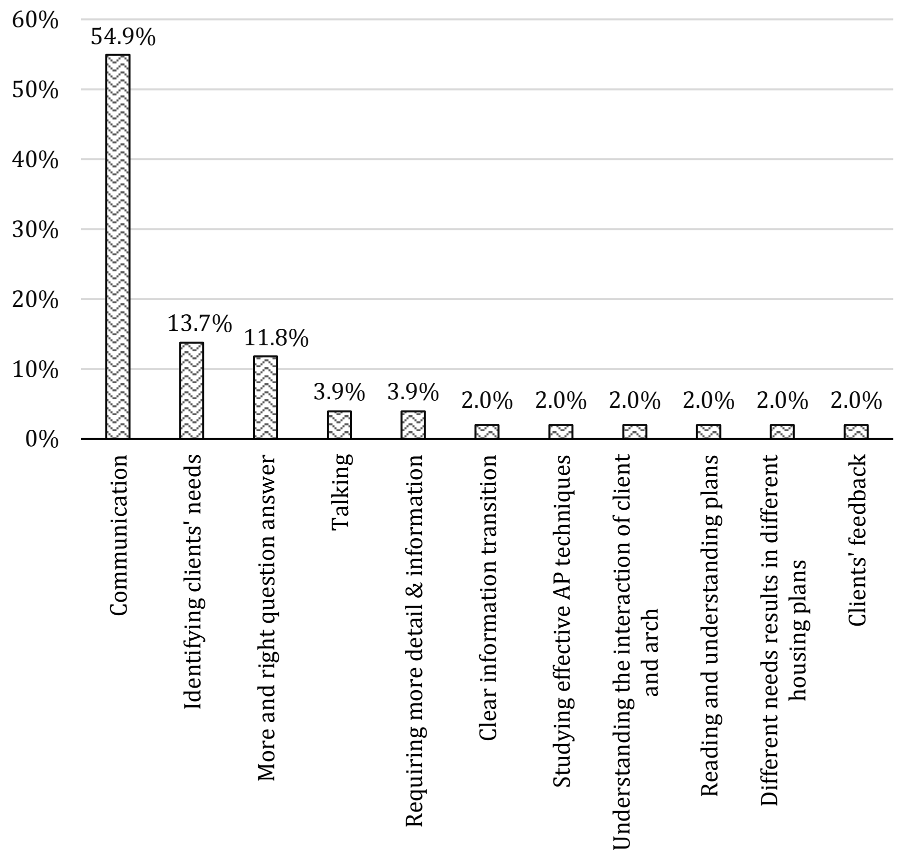

Figure 15: Recognized Architectural Programming lean Simulation Goals by Participants

The observation made through the questionnaires is that, players perceived this simulation to be a useful tool to indicate the importance of communication and identifying owners’ expectations which ultimately outlines the importance of a utilizing a comprehensive AP tool in the construction industry.

Other evaluations were conducted to assess difficulty and enjoyable levels of the Architectural Programming lean Simulation. Figure 16 graphically depicts the difficulty level of this simulation ranging from “1-Hard to understand” to “6-Easy to understand,” and approximately seventy-one percent (70.6%) of players believed that this simulation was moderately easy and easy to understand.

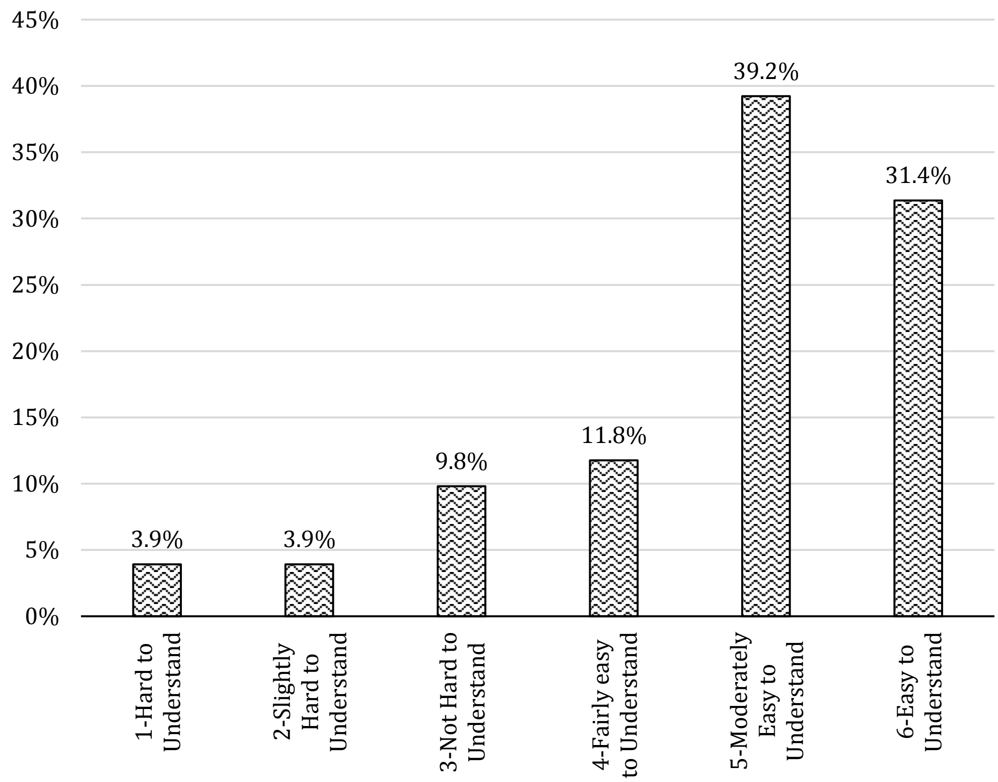

Figure 16: Difficulty Level of the Architectural Programming Lean Simulation to Understand

Figure 17 conveys how enjoyable it was to play the simulation. Approximately seventy-three percent (72.6%) of players agreed that this simulation is very fun and extremely fun to play.

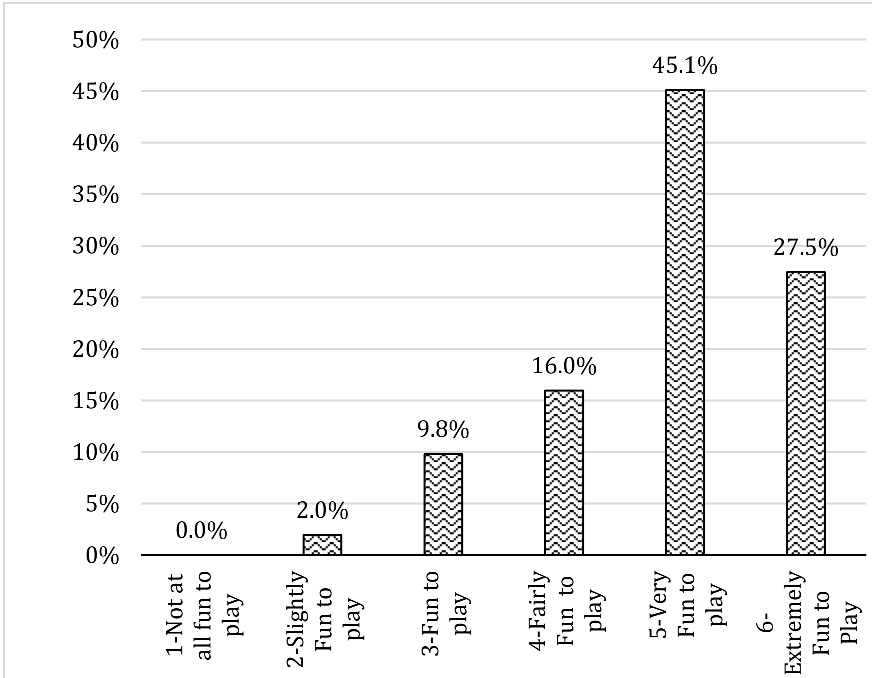

Figure 17: The Architectural Programming Lean Simulation Enjoyable Level Comparison

Participants' demographic data were also analyzed and illustrated in graphs. As indicated in Figure 18, eighty-six percent (86%) of participants were male players, and fourteen percent (14%) of them were female players.

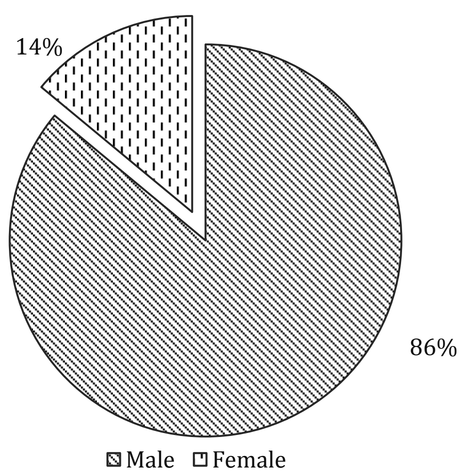

Figure 18: Gender Distribution

Approximately seventy percent (70.6%) of the players were undergraduate students, and thirty percent (29.4%) of therm were graduate students (Figure 19).

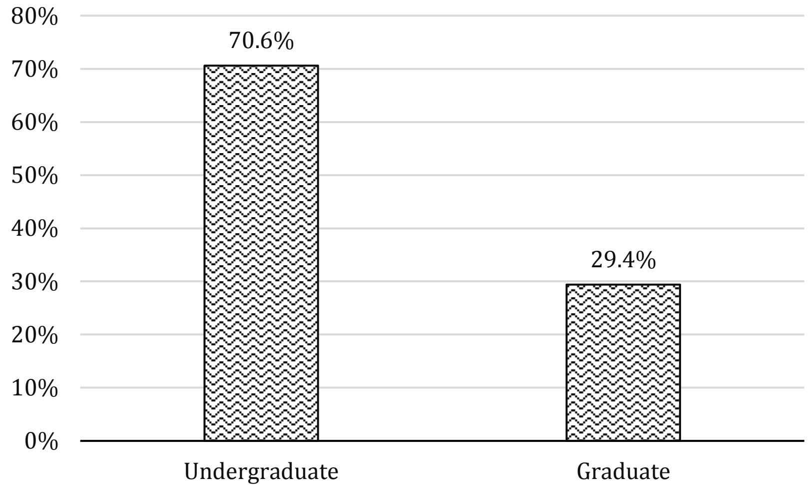

Figure 19: Participants' Educational Classification

In Figure 20, players’ educational majors were classified based on the academic degree they planned to earn within five years. Majors included Architecture (ARCH), Business Administration (BA), Civil engineering (CVEN), and Construction Science (COSC).

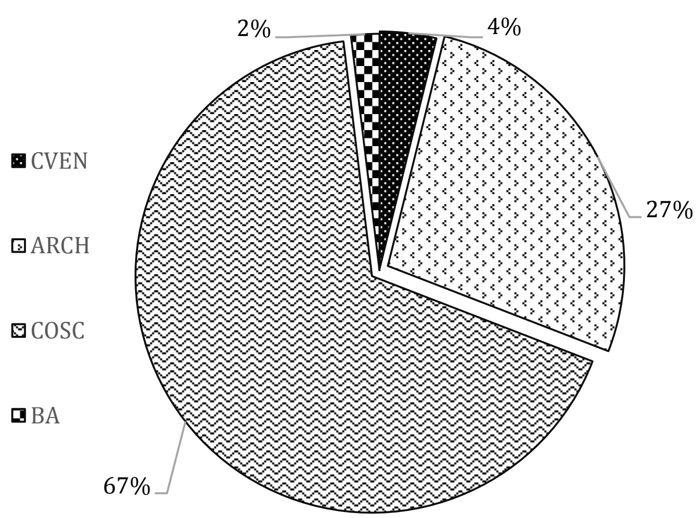

Figure 20: Participants' Academic Major

Graduate students' background with associated frequency are outlined in Table 10.

Table 10: Graduate participants' undergrad majors and their frequency

Graduate Major	**ARCH**	**ARCH**	**ARCH**	**COSC**	**CVEN**	**CVEN**
Under Graduate Major	Architecture Engineering	Environmental Design	University Studies of Architecture	CVEN	CVEN	Machinery Design
Frequency	1	4	7	2	1	1

In conclusion, outcomes of the Architectural Programming lean simulation suggest that there is a significant alignment between an owner's expressed needs and an architect's design after AP method is implemented.

This simulation also scored well above average in terms of level of fun to play and ease to understand. These scores outline the convenience of this innovative lean simulation with respect to being played at organizations for the purpose of teaching the importance of AP in construction and other related fields.

Overall feedback from participants was categorized into four subsets including:

- Instruction;
- Simulation process;
- Simulation content; and
- No constructive comment.

About forty-seven percent (46.8%) of participants' comments were related to the Simulation content which contains the Game content, Time, and Question and answer subcategories. Figure 21 indicates which subset requires recommended improvement for future development.

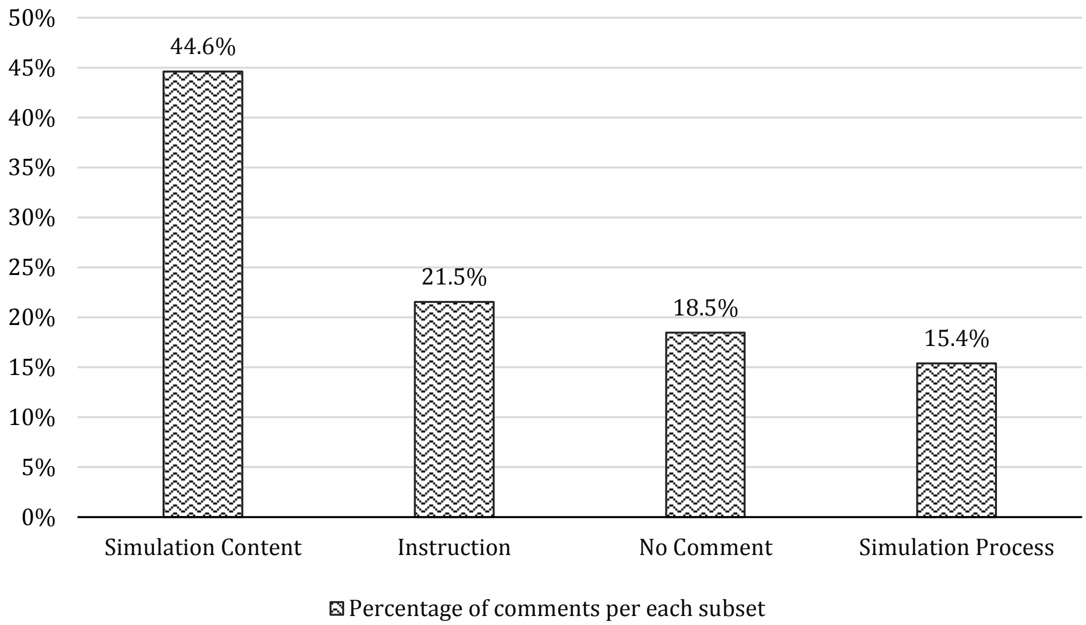

Figure 21: Participants' feedback per each subset of the Architectural Programming simulation

Additionally, Table 11 provides details pertaining to players' comments regarding how the author can improve the Architectural Programming simulation. Some frequent statements are as listed below:

- This simulation is a good game;
- Provide more clear instruction;
- Provide more time;
- Permit more questions and guesses during round 1.[10]

Table 11[11]: Participants' Comments on approaches to improve the Architectural Programming lean Simulation

Subset Description	Frequency	Repetition Percentage
1- Instruction	**14**	**21.5**
Be more clear about the entire process	6	9.2
Improve the instructions	2	3.1
Include the brief process of game	1	1.5
Provide written instruction	3	4.6

[10] The author believes this feedback may reflect a misunderstanding of some participants of the purpose of the simulation.

[11] Table 11 continues to page 36.

Table 11 Continued

Subset Description	Frequency	Repetition Percentage
Mention that this game is deductive reasoning	1	1.5
Ask participants to raise their hand when the facilitator wants to hand over the sheets	1	1.5
2- Simulation Process	**10**	**15.4**
Give an example	1	1.5
Make the game more interesting	1	1.5
Add another round in order to architects get feedback from their Owners and ask them some questions to remove the ambiguity for making correct decisions	2	3.1
Flip the drawing number bars from the bottom to top on the layout sheets	2	3.1
Cost was not useful	1	1.5
Nothing for owner to play	1	1.5
It is too simple	1	1.5
Provide more people in a group	1	1.5
3- Simulation Content		
3.1- Game Content	**10**	**15.4**
Provide amenities for the properties	1	1.5
Provide an owner whose specific needs aren't met by any existing floor plan	1	1.5
Add some finishes such as flooring to the list of things to guess	1	1.5
Make it more complex and specific	2	3.1
Add more layouts	2	3.1
Add more variables to the game	2	3.1
Provide additional details to the plans for increasing scenario options	1	1.5
3.2- Time	**8**	**12.3**
Provide less time to put pressure on the architects.	1	1.5
Specify the time participants can guess	1	1.5
Provide more time	6	9.2
3.3- Q & A	**11**	**16.9**
Provide the opportunity for architects to answer their questions more freely (more than Y/N question)	2	3.1
Add more question on round 1	6	9.2
Be more specific on what can be asked on round 1	1	1.5
Number of questions on round 1 was confusing	1	1.5
Add one more question or information on round 2	1	1.5
4- No Constructive Comment	**12**	**18.5**
Total	**65**	**100**

Table 12 provides a summary of participant perception of the best parts of the game.

Comments were classified into eight (8) categories, including:

- Game process;
- Owners' requirement description;
- Floor plan layouts;
- Guessing;
- Communication;
- Real-world experiment;
- Enjoyable to play; and
- Other

Table 12[12]: Participants' comment on the best parts of the Architectural Programming lean simulation

Subset Description	Frequency	Repetition Percentage
Game process	**14**	**24.1**
Having a team mate to guess based on the limited information	1	1.7
It helps you to realize possible needs that might affect potential owners	1	1.7
Seeing how far off the architect was after the first round.	1	1.7
Having an interactive game in class.	1	1.7
Two tries allow users to learn the lesson.	1	1.7
The architect having to ask the right questions and the owner having to say his story.	1	1.7
Having the architect made it.	1	1.7
Asking two questions.	1	1.7
The frustration of only 2 answers.	1	1.7
I enjoyed how the game was secretive.	1	1.7
The interaction between architects and owners.	1	1.7
The physical plans in hand.	1	1.7
Seeing how close I was to be successful.	1	1.7
Owners' requirement description	**14**	**24.1**
Giving an explanation of who I am as an owner to the architect, so he could narrow down what housing I need.	1	1.7
The difference in detail from RND 1 and RND 2.	1	1.7
The more detail provided, the easier it was to select the correct floor plan.	1	1.7

[12] Table 12 continues to page 39.

Subset Description	**Frequency**	**Repetition Percentage**
The satisfaction of getting the whole story.	1	1.7
Reading owners' detail and description.	2	3.4
The best part of the game is seeing how much of difference it made by knowing just a few more traits of the family vs. just two facts	1	1.7
It shows that more information you have the better and more accurate your work can be.	1	1.7
The best part was reading the scenario and taking in all consideration to make a choice	1	1.7
The story sheet made it a lot easier to understand what the owner wanted and make a guess based on that.	1	1.7
Owners told architects life story and their preference, so architects could design to meet them.	1	1.7
Reading the description of owners' demand is an efficient way to tell architect what owners want.	1	1.7
Learning what questions to ask to design a program and learning what to listen during Owners' narrative.	1	1.7
Giving hints to the architect.	1	1.7
Floor plan layouts	**6**	**10.3**
Looking at various floor plans and seeing how owner needs are important when choosing a housing unit.	1	1.7
Prepended different plans in which differed aspects of owners' requirements were considered.	1	1.7
The number of different floor plan options was the best part. It made the game look impossible at first then showed hoe some information can lead you to an option.	1	1.7
Seeing the difference of architecture.	1	1.7
Be able to identify the difference between apartments.	1	1.7
Seeing multiple layout options to figure out owners' needs.	1	1.7
Guessing	**11**	**19.0**
Hearing if my (architect's) guess was correct.	1	1.7
Trying to guess what room the owner wanted by understanding their needs.	1	1.7
Trying to guess what room the owner wanted by understanding their needs.	1	1.7
Trying to locate the floor plans, and narrowing them down.	1	1.7
Trying to guess what owners wanted as a home.	1	1.7
The guessing if you are correct.	1	1.7
The guessing of the prices.	1	1.7
I liked it when the architect had to guess just based on the owner’s situation.	1	1.7
The guessing which floor plan was the correct one.	1	1.7

Table 12 Continued

Subset Description	**Frequency**	**Repetition Percentage**
Try to guess the layout by specifying questions, then see if you improved by the second round.	1	1.7
When the architect was trying to guess that layout of the apartment.	1	1.7
Communication	**3**	**5.2**
Communication	1	1.7
Showing how important is communication.	1	1.7
Great way to demonstrate how important communication is.	1	1.7
Real-world experiment	**4**	**6.9**
Felt like a real life.	1	1.7
Using a simulation to give a real world example.	1	1.7
How owners' information was provided in a real manner.	1	1.7
Putting yourself in someone else's shoes.	1	1.7
Enjoyable to play	**3**	**5.2**
It is fun to participate.	1	1.7
Simple and easy to play.	1	1.7
The overall game was interesting to play.	1	1.7
Other	**3**	**5.2**
While hearing owners' needs and see how it narrows down the floor plans to a specific one.	1	1.7
Comparing the floor plans to each other (prices, bedrooms, etc.).	1	1.7
Need for intuitive thoughts.	1	1.7
Total	**58**	**100**

9. DISCUSSION

The Architectural Programming lean simulation was an attempt to identify the importance of reliable architectural programming (AP) methods on OAEC projects. Preliminary feedback from simulation players indicates that this simulation can be applied to real-world scenarios. The questionnaire did not ask if the simulation participants assumed the role of architect or owner when playing the game. It is recommended for future studies to provide such question during the simulation process.

Many studies have been conducted in the field of Lean Construction and Architectural Programming individually, but there is little published work that addresses both simultaneously. The aim of this research is to integrate lean strategies and Peña's AP components to fill this gap. Indeed these methods can both coexist and complement one other. This research proposed a new AP table for Target Value Design (TVD) that integrates Lean Construction principles of plus/ delta **(+/Δ)** with Peña's Programming elements Figure 12 (Figure 22).

	Facts	Current State		Future State
		+	Δ	Goals
Function				
People				
Activities				
Relationship				
Form				
Site				
Environment				
Quality				
Economy				
Initial Budget				
Operating Costs				
Lifecycle Costs				
Time				
Past				
Present				
Future				

Figure 22: Proposed architectural programming method

By inserting plus/ delta (**+/Δ)** into Peña's AP method, the programming method becomes compatible with Lean Construction concept of continuous improvement. By applying Δ, one of the key concepts of lean philosophy – "Kaizen" or continuous improvement – will be incorporated into the programming process. Figure 23[13] depicts a Kaizen stairway in which distance between current and future states can be spanned through a continuous series of Δ's in the proposed AP. The Vertical axis on the Kaizen stairway demonstrates that time, cost, quality, safety, and morale will be enhanced by striving toward better future states. This feature of kaizen stairway overlays Peña's programming components and enables the owner-architect partnership to maximize desired value not through a single programming session, but rather through an iterative process of inquiry.

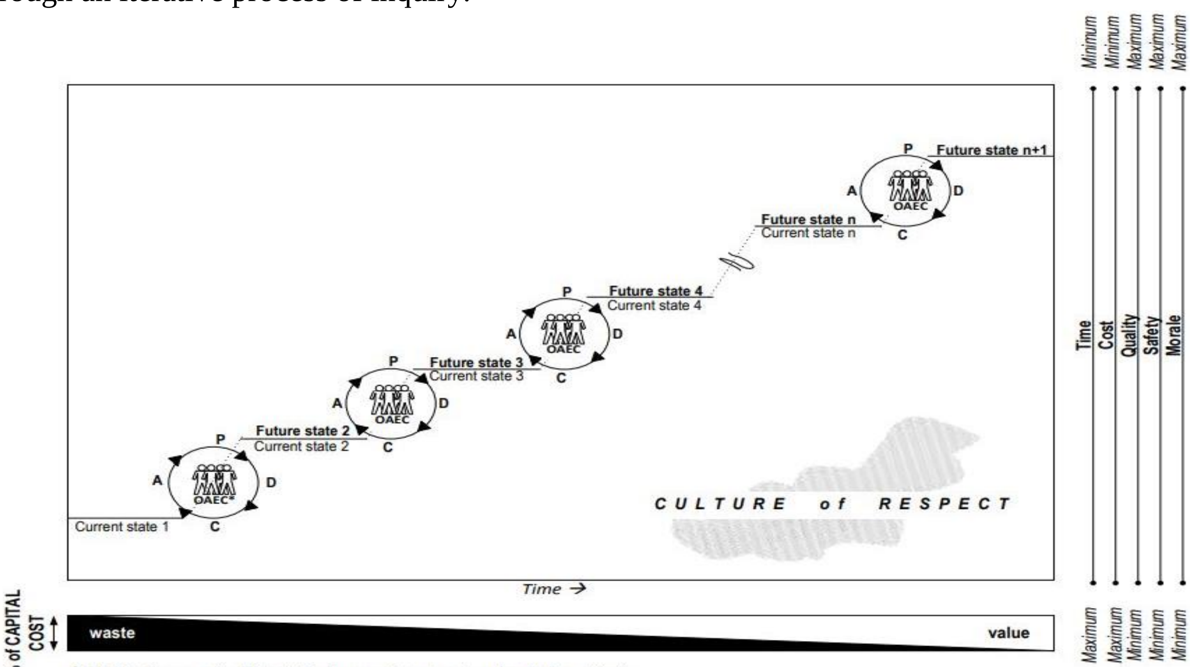

Figure 23: "Kaizen Stairway": The continuous improvement process of lean construction, Reprinted from Rybkowski and Kahler 2014 (Figure 1, p1260)

[13]*Reprinted with permission from "Collective kaizen and standardization: the development and testing of a new lean simulation." by Rybkowski, Z. K., & Kahler, D. L, 2014, Proceedings of IGLC, The International Group for Lean Construction (2014), Oslow, Norway, pp. 25-27, Copyright 2014 by IGLC.

10. CONCLUSION

Project success has been defined by two key factors including managing costs to achieve efficiencies, and creating and enhancing value. Lean Construction strategies can be applied in order to create and improve values in construction projects. However, fifty-three percent (53%) of construction projects are underperforming overall. Poorly defined scope of work by OAEC stakeholders has been identified as the most frequent reason for project cost overruns. By improving the architectural programming stage of a project, stakeholders can improve scope of work related to owners, meet their expectations and requirements, and ultimately, increase the probability of project success. This paper was an attempt to integrate lean strategies and Peña's AP method to fill a gap that synergistically integrates needs of owners, architects, engineers, and contractors when embarking on Target Value Design.

The intent of this research was to develop and test an innovative simulation to effectively highlight the value of architectural programming and its associated long-term benefits, thus helping to reduce cost overruns and increase project success among OAEC stakeholders. After playing the Architectural Programming simulation, participants indicated they understood the importance of architectural programming in the construction industry. Student participants in this study were potential stakeholders in the construction industry, and it would be worthwhile for a future longitudinal research projects to explore whether their understanding endures or is transformed as the student participants pursue careers following graduation.

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APPENDIX A

<u>Script for Facilitator to Read Aloud During Simulation</u>

Howdy!

"My name is Ellie and I am inviting you today to participate in a lean simulation experiment. At the moment you won't know exactly what I testing so just play along and have fun. We will talk the purpose of the experiment after it is over."

"But first I will pass out a consent form which you need to sign before playing. Take a moment to read it and I will come around to collect your signed forms when you are ready." (Hand out forms)

"First you need to break into teams of two. Please count off as A and B. (count off). A's—you will be Architects. B's you will be owners. I will also give you group numbers on a post-it note." (Hand out post it notes with group numbers).

"All B's (owners) you need to each draw one slip of paper. Turn it over when you get it and don't let the architects see what you have".

"Each of you should have two sets of plans labeled 1 and 2. Please take a moment to look closely at the plans. See how they are organized. Keep in mind that Plans 1 represent Closed Kitchen apartment layouts and Plans 2 is for Open Kitchen apartment layouts. Also notice that there is a north arrow in the upper right hand corners. Can someone please tell me where the sun is located in the northern hemisphere (i.e. the US)? (i.e. the south)? Where does the sun rise? (in the east) And where does it set? (in the west). Be aware that it is the opposite in the southern hemisphere". "You will play two rounds of this game. Right now we will play Round 1".

<u>ROUND I</u>

"Architects and Owners: Please hold up your plans in front of you face so you cannot see where the other person is looking while they are studying the plans".
To the "Owners: The number you drew is the floor plan **and** cost per sf you want. To the Architects: You will have to figure out the identification number of the plan **and** cost the owner wants. You will only be allowed to ask two (2) Yes or No questions before guessing. For example, you cannot ask "How many bedrooms do you want?" But you can ask: "Do you want a two-bedroom house?"

"I will now go around the room and the Owners need to draw out a slip of paper which describes the plan they want. Please don't begin until I give you the go-head and Owners please remember to hide your number from your Architect."

After all have drawn their numbers, facilitator gives them the go-ahead to begin to ask 2 Yes-No questions. (Wait 4 minutes).

"Now we will go team-by-team to see if the Architects were able to guess the correct plan." Facilitator writes on board for all to see:

RND I	Team #											
	1		**2**		**3**		**4**		**5**		**Etc.**	
Guessed Dwg # and Price												
	Y	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**

RND II	**1**		**2**		**3**		**4**		**5**		**Etc.**	
Guessed Dwg # and Price												
	Y	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**

ROUND II

"For the second round, I will give the owners a table of information which include the needs and requirements of the owner. The owners should slowly read their story to their architect. The architects will each have a blank table to fill in as you listen to the owner. Architects are not permitted to ask any questions but may request that the owner read their story again. Again, architects fill in their table as they listen and then must write in their guess of both the plan number **and** the cost per square foot." Participants will be given 6 minutes.

The facilitator now asks each team to declare their guesses for Round II.

The facilitator discusses the tabulated outcomes with the participants.

Ask them:
"Why do you think there was a difference between the two rounds?"

"In a real discussion between an architect and an owner, can you imagine additional questions that should be asked?"

"What do you think is the purpose of this exercise?"

Facilitator now projects a scan of the Peňa programming and Target Value Design – architectural programming table. Facilitator should distribute the following questionnaire at least 5 minutes before the end of class.

APPENDIX B

Slips to Hand Out to Owners to Draw from a Bowl

Cut Here

C4-1 ($60/SF)	E3-1 ($300/SF)
D4-2 ($150/SF)	B3-2 ($60/SF)
D3-1 ($150/SF)	A2-2 ($150/SF)

Sheet to Give to Architects

Template for scenarios

1	# of bedrooms	
2	Ability / Disability	
3	Solar Orientation	
4	Open vs. closed kitchen	
5	Cost	

Plan Number________________Cost / SF______________________

Sheets to Give to Owners

C4-1 ($60/SF)	
1	I'm an international, male graduate student seeking an apartment with a roommate to share the cost. But I want privacy and to have my own bedroom.
2	I am an excellent tennis and soccer player and in perfect health.
3	Since this is in a cold climate in Canada, I would like natural sunlight to come though my bedroom, warm the room, and help me study better.
4	I frequently talk to my girlfriend on my cell phone while I'm cooking at the end of a long day so would like to have privacy when I do this.
5	As a student, I am living on student loans and don't have much money so need to economize.

D4-2 ($150/SF)	
1	I'm an international, female undergraduate student seeking an apartment with a roommate to share the cost. But I want privacy and to have my own bedroom.
2	I had an accident last year and am recovering with physical therapy. They tell me it will take a few years before I can easily climb stairs without crutches.
3	Since this is in a cold climate in Norway, I would like natural sunlight to come though my bedroom, warm the room, and help me study better.
4	I like cooking with friends and want to invite them over. It would be good to be able to have dinner parties and talk to friends in the living room while I'm cooking.
5	I come from a middle-class family who saved money for my college education. We aren't rich, but I can afford a better place than the lowest cost apartments.

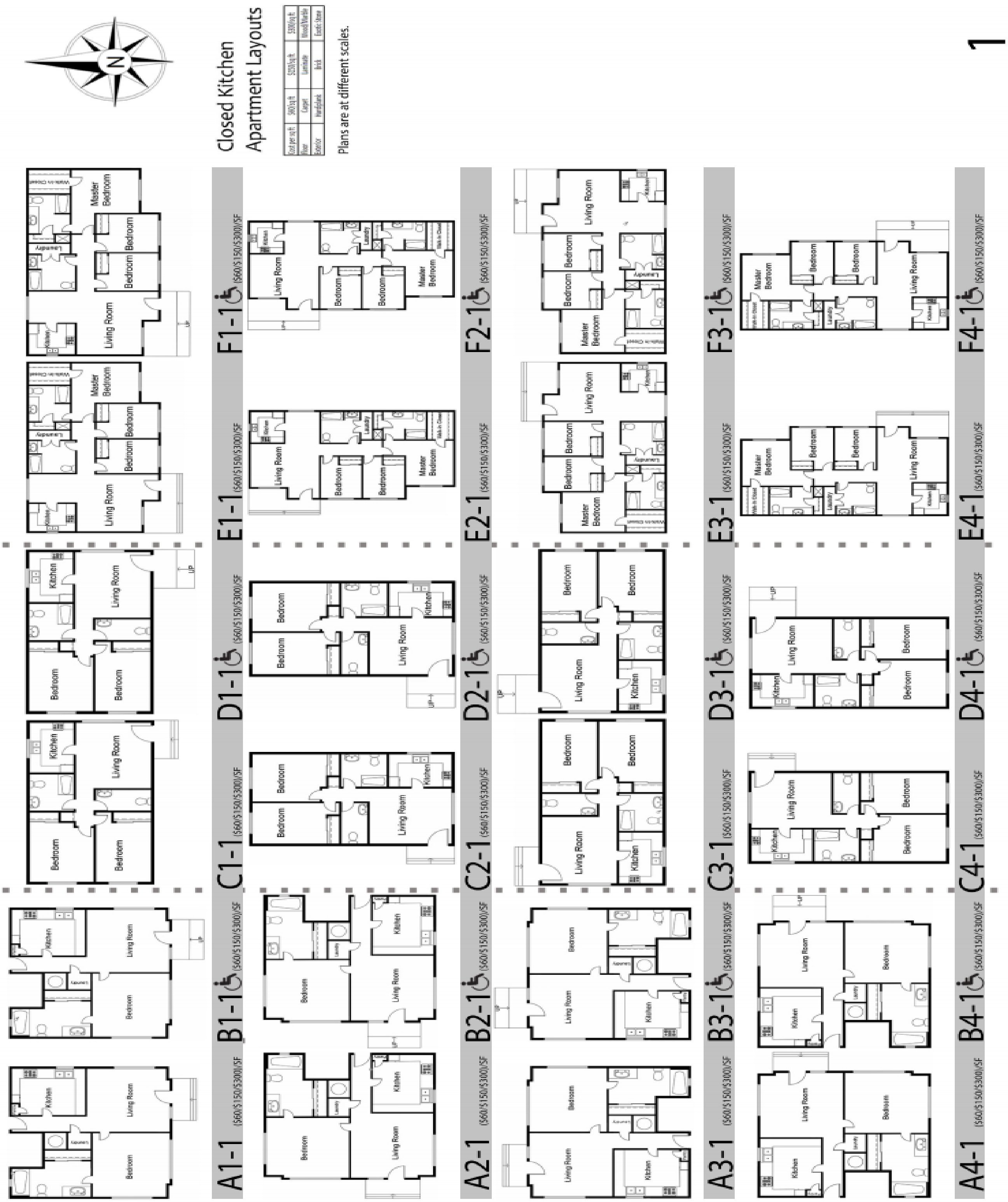
D3-1 ($150/SF)	
1	I’m an international, male graduate student seeking an apartment with a roommate to share the cost with my twin brother. But I want privacy and to have my own bedroom.
2	My brother had an accident when he was young so has to use a wheelchair.
3	My twin brother and I are a morning person so we really want to have morning sunlight when we wake up each day.
4	We love to make and eat very spicy food. In the past the landlord kept our deposit, complaining he had to steam clean the carpets and drapes after we left because of the food smell. So we instead would like an enclosed kitchen so the smell is contained.
5	We come from a middle-class family who saved money for our college education. We aren’t rich, but we can afford a better place than the lowest cost apartments.

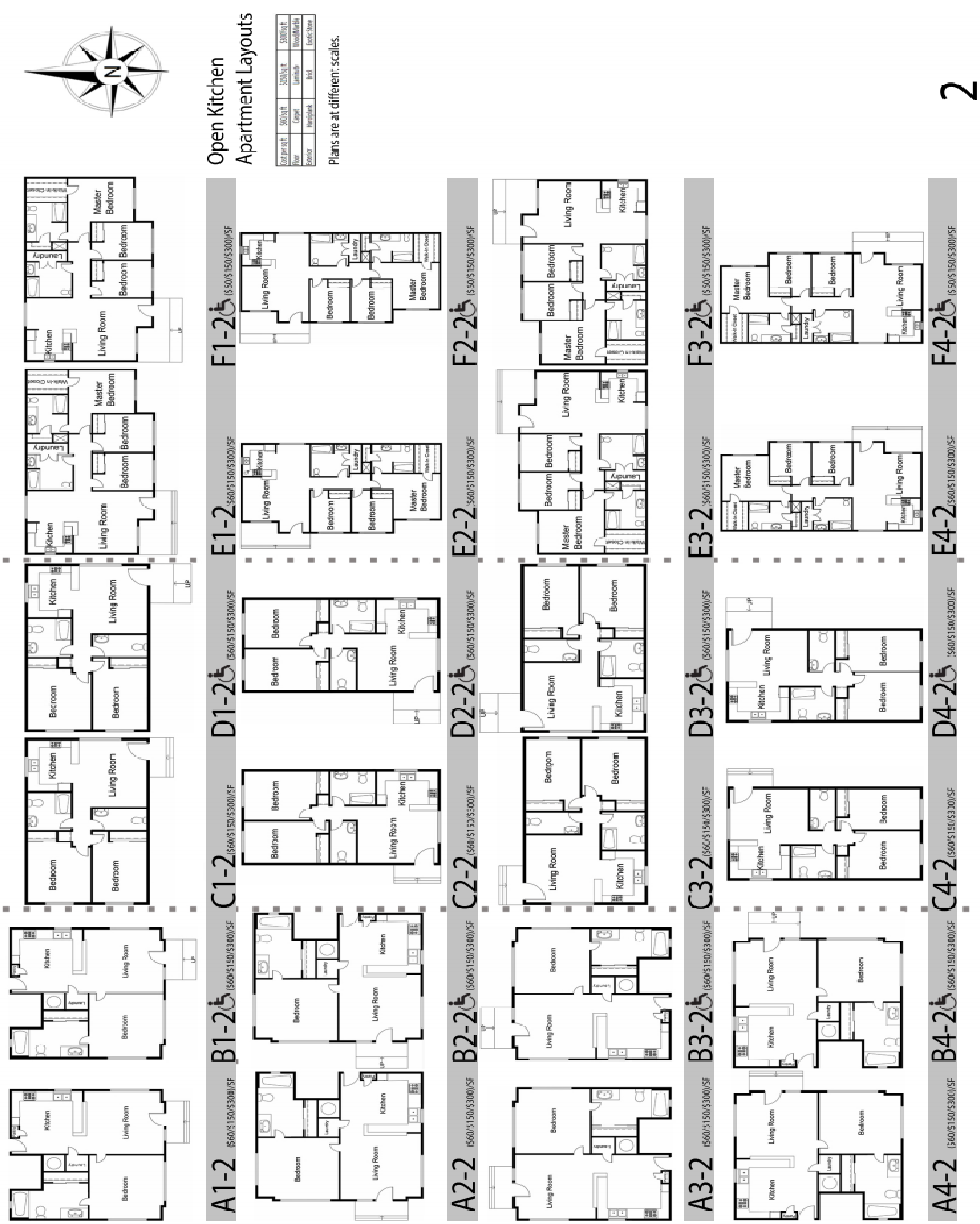
E3-1 ($300/SF)	
1	My wife and I have a 17-year old teenage daughter and a 9-year old son. The children need to have their own bedrooms.
2	Everyone is healthy and my wife and I are very active.
3	We live in a part of New Zealand (i.e. southern hemisphere) which is so cold it has penguins. Give us sun in our bedrooms and living room please!
4	I am the cook in the family and like peace and quiet when I cook after work. The kids like watching TV in the living room which can be noisy, so I want some barrier between us.
5	I am a data scientist and make good money so cost is not a constraint.

B3-2 ($60/SF)	
1	My husband and I are retired and 65 and 60 years old, respectively.
2	We are currently in good health but want a place to live well into our 70s or even 80s, assuming we live that long.
3	We live in Arizona which is really hot. So we don’t want to have direct sunlight in our bedroom at midday when we take naps. We also don’t want sunlight in the afternoon in our bedroom.
4	We have young grandchildren and will be taking care of them during the day while their parents are at work. We want to be able to supervise them while they play in the living room, even while we cook.
5	We are living off of social security so need a modestly-priced home.

A2-2 ($150/SF)	
1	I am a night security guard in New York City and prefer to live alone.
2	I lift weights when I can and am in tip-top shape.
3	Since I work at night and sleep during the day I don’t want light coming into my bedroom.
4	I have a great film collection, and want to be able to see my plasma screen in the living room while I am cooking.
5	I am solidly middle-class. I’m not rich but I’m not poor either.

<u>Plan Sheets to Give to Each Participant (Sheet 1 and 2 should be given to each)</u>




Open Kitchen
Apartment Layouts
Plans are at different scales.
A1-2 ($60/$150/$300)/SF
B1-2 ($60/$150/$300)/SF
C1-2 ($60/$150/$300)/SF
D1-2 ($60/$150/$300)/SF
E1-2 ($60/$150/$300)/SF
F1-2 ($60/$150/$300)/SF
A2-2 ($60/$150/$300)/SF
B2-2 ($60/$150/$300)/SF
C2-2 ($60/$150/$300)/SF
D2-2 ($60/$150/$300)/SF
E2-2 ($60/$150/$300)/SF
F2-2 ($60/$150/$300)/SF
A3-2 ($60/$150/$300)/SF
B3-2 ($60/$150/$300)/SF
C3-2 ($60/$150/$300)/SF
D3-2 ($60/$150/$300)/SF
E3-2 ($60/$150/$300)/SF
F3-2 ($60/$150/$300)/SF
A4-2 ($60/$150/$300)/SF
B4-2 ($60/$150/$300)/SF
C4-2 ($60/$150/$300)/SF
D4-2 ($60/$150/$300)/SF
E4-2 ($60/$150/$300)/SF
F4-2 ($60/$150/$300)/SF
2

APPENDIX C

<u>Advance information distributed to participants as required and approved by TAMU's Institutional Review Board (IRB)</u>

EMAIL COMMUNICATION SENT TO PARTICIPANTS

From: Solhjou Khah, Fatemeh.

To: [Potential Participants]

Subject: Request for Participation: Testing an Innovative Architectural Programming Simulation as a Precursor for Target Value Design Survey

Date:

Dear students:

You have been identified as a potential participant for a research study intended to test an innovative lean simulation which illustrates architectural programming.

You were selected to be a potential participant because of your specific knowledge and expertise in architecture, construction science, civil engineering, real estate, and/or a related field.

This study is being conducted in partial fulfillment of master's requirements in Construction. As a participant, you would receive a copy of the final research.

I would like to formally invite you to participate in this study, and ask you to recommend other potential participants by contacting me. My contact information is listed below for your convenience.

If you agree to participate in this study, it will take approximately 50-60 minutes of your time, requiring playing a simulation (game) and completing a survey.

I will follow up with you in 3 days and will ask for your commitment at that time. Thanks in advance for your cooperation.

Sincerely,

Fatemeh Solhjou Khah, Graduate Student

Texas A&M University

Construction Science Department 5

74 Ross St, Room 317 College Station, TX 77845-2116

Tel: (979) 845-1017

E-mail: <u>ellie_91@tamu.edu</u>

Consent Form

Developing and Testing an Innovative Architectural Programming Simulation as a Precursor to Target Value Design

You are invited to take part in a research study being conducted by Ms. Fatemeh Solhjou Khah and Dr. Zofia Rybkowski, researchers both from Texas A&M University. If you decide to take part in the study, you will be asked to mark the "I Agree" section at the bottom of this page.

The purpose of the study is to collect feedback after testing of an innovative simulation. You are being asked to participate in this study because you are acquainted with the field of architecture, civil engineering, construction science and/or real estate. Up to 200 people in the entire study will be enrolled. The study will be conducted in the summer and Fall 2018.

Your point of view will be beneficial for a research study focused on a new architectural programming simulation. You will be asked to complete a survey designed for the study to evaluate the simulation. The participation in this study will last approximately 50-60 minutes. Information about you will be kept confidential to the extent permitted or required by law. Those who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Research Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on to you. We also assure you that no individual will be identified in any documents and reports that are produced as a result of the study.

There is no compensation for your participation on this survey. In addition, the risks associated in this study are minimal, and are not greater than risks ordinarily encountered in daily life. Although the researchers have tried to avoid risks, you may feel that some questions and charts that are asked of you will be stressful or upsetting. You do not have to answer anything that you do not want to. Moreover, there are no direct benefits to you. The results will assist researchers gain a better understanding of the effectiveness of the simulation you will play.
You may contact Dr. Rybkowski to inform her of any concern or complaint about this research at 979.845.4354 or zrybkowski@tamu.edu. For questions about your rights as a research participant, to provide input regarding research, or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Research Protection Program office by phone at 1-979-458-4067, toll free at 1-855-795-8636, or by email at irb@tamu.edu.

I Agree **I Don't Agree**

Questionnaire

An Innovative Architectural Programming Simulation

1. What is your age? ---------------------
2. What is your gender? ---------------------
3. What is your department? ---------------------
4. Circle your classification (Undergrad/ Grad/ Neither)
5. What is/was your undergraduate major (if applicable)? ---------------------
6. What is/was your graduate major (if applicable)? ---------------------
7. What do you think was the purpose of this simulation?

8. Do you think the instructions were easy to understand? Please answer on a scale of 1 to 6.

Hard to understand	1	2	3	4	5	6	Easy to understand

9. Do you think the game was fun to play? Please answer on a scale of 1 to 6.

Not at all fun to play	1	2	3	4	5	6	Extremely fun to play

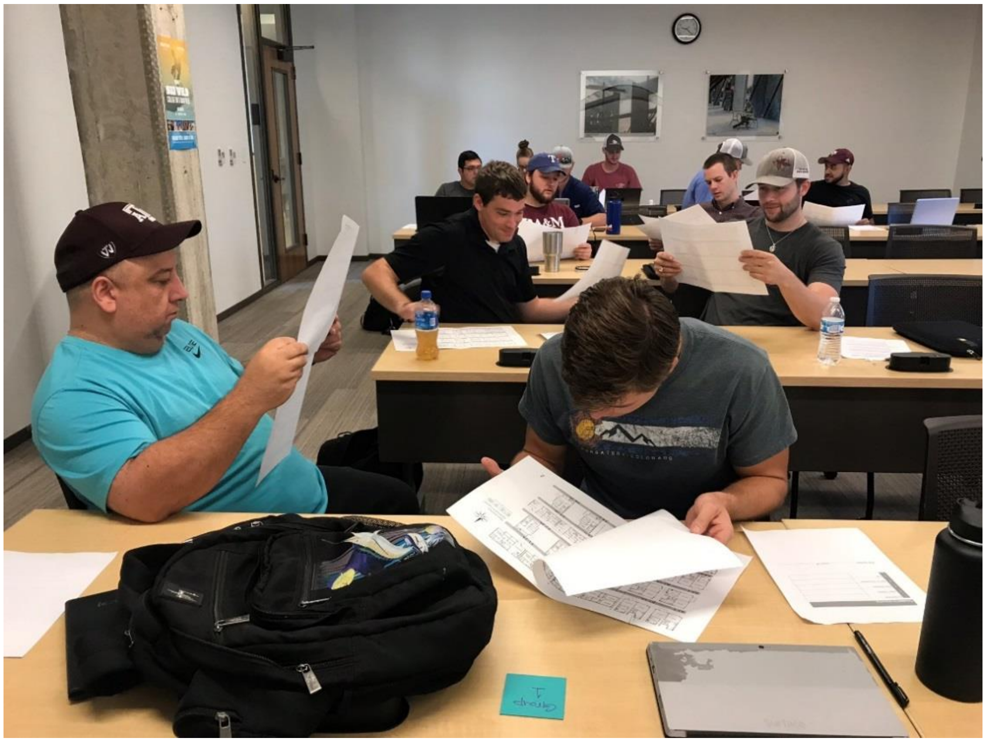
10. How do you think this simulation is applicable to an actual project?

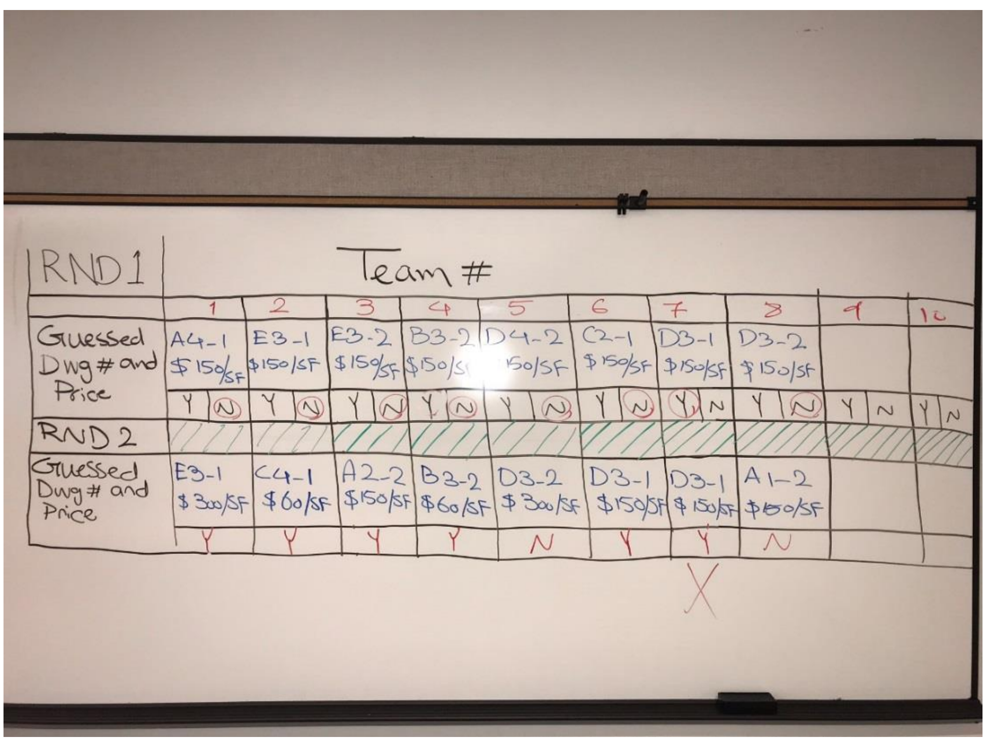
11. What were the best parts of the game? Please be specific**.**

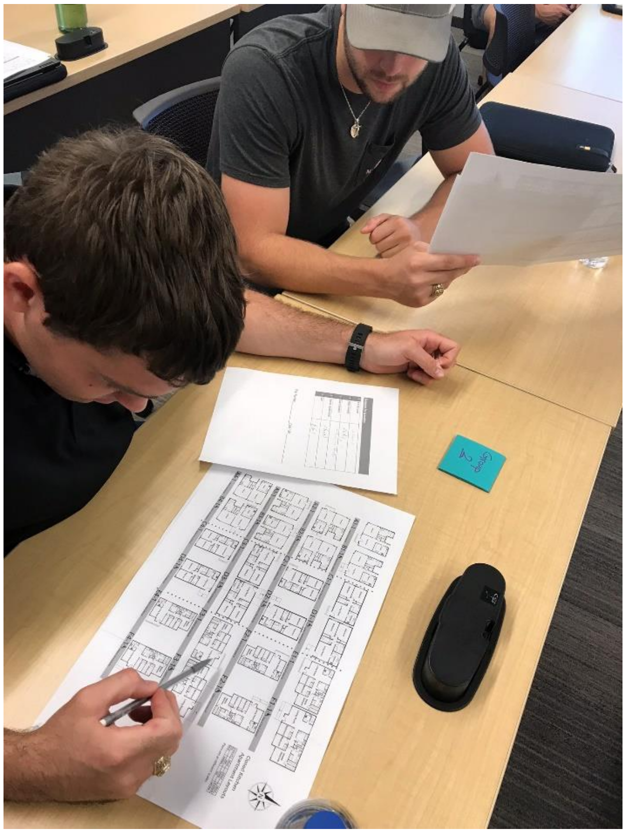
12. What could be improved? Please be specific.

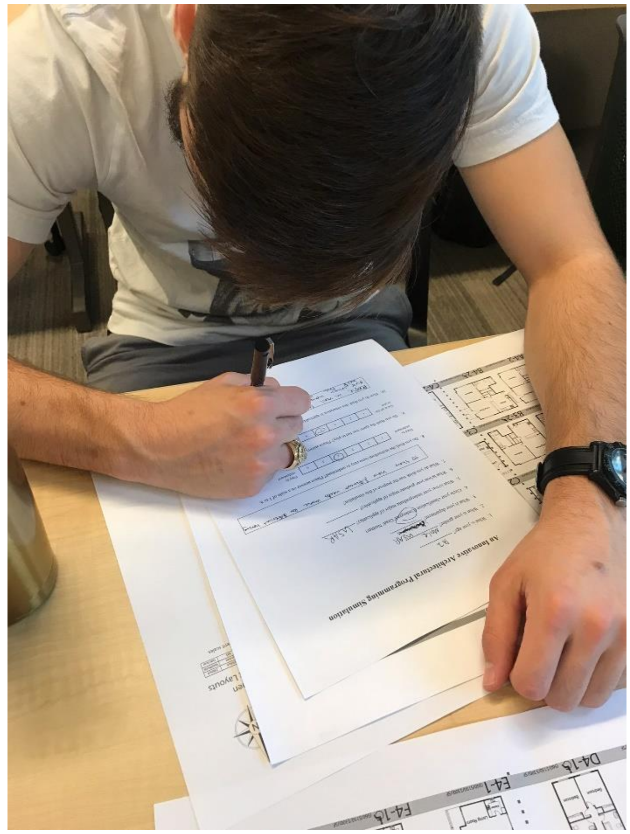
APPENDIX D

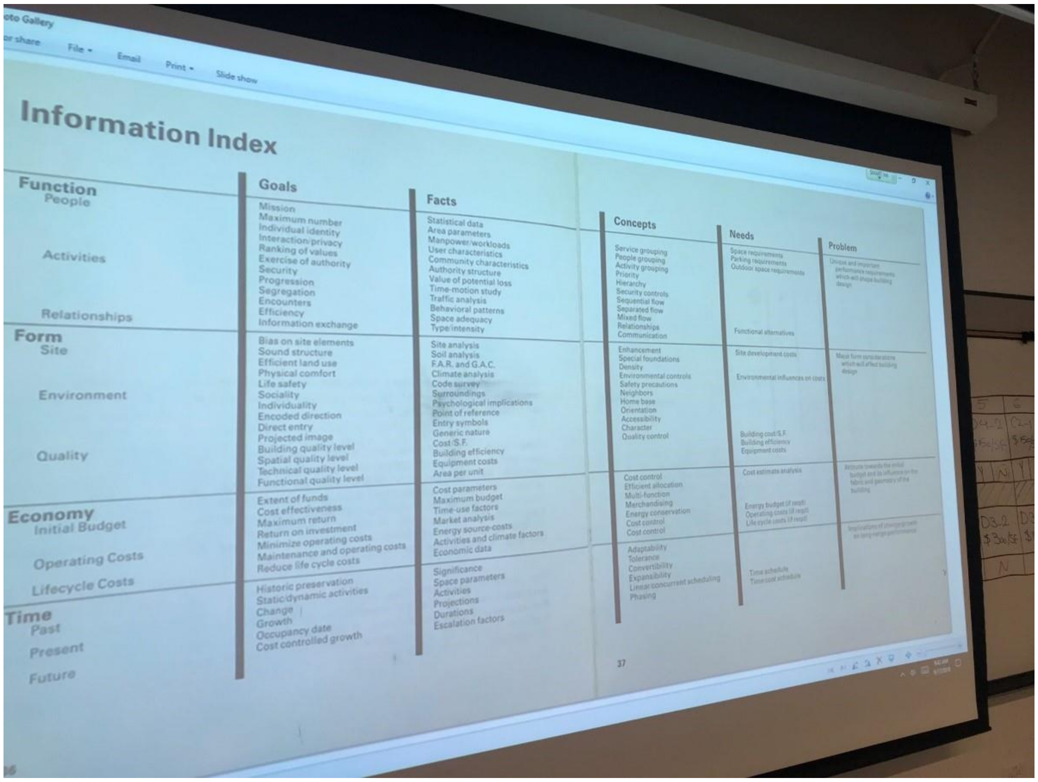
<u>Images of Participants While Playing the Game</u>

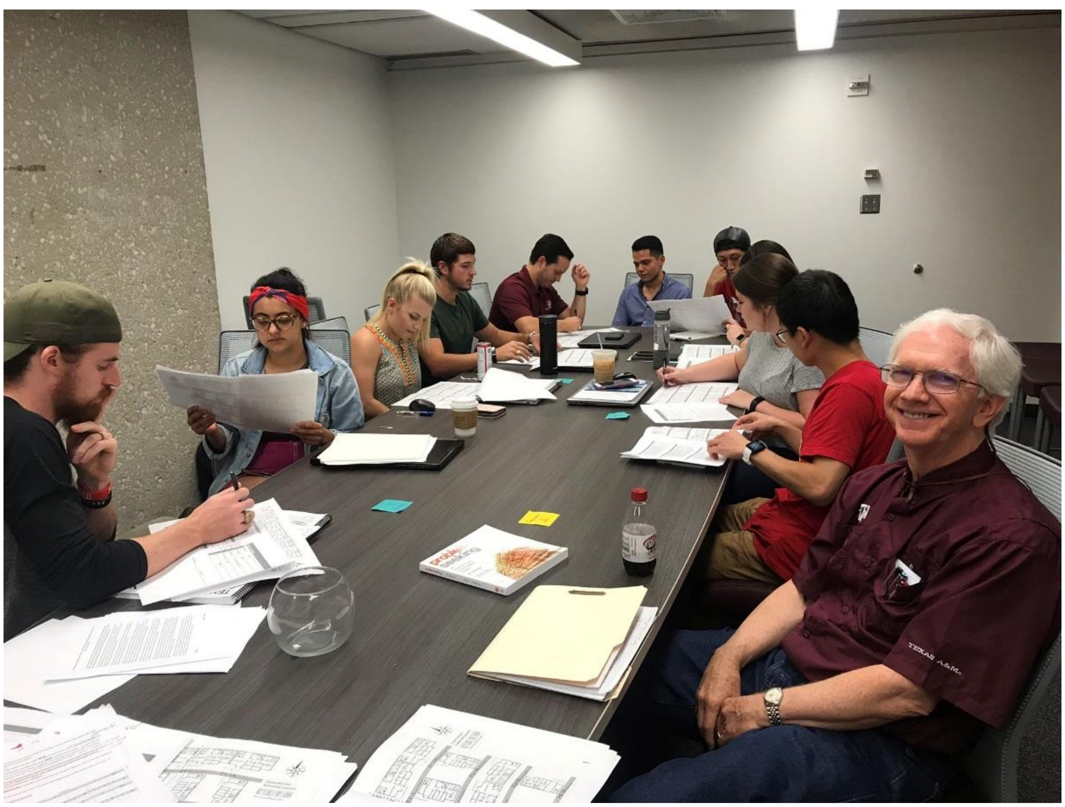


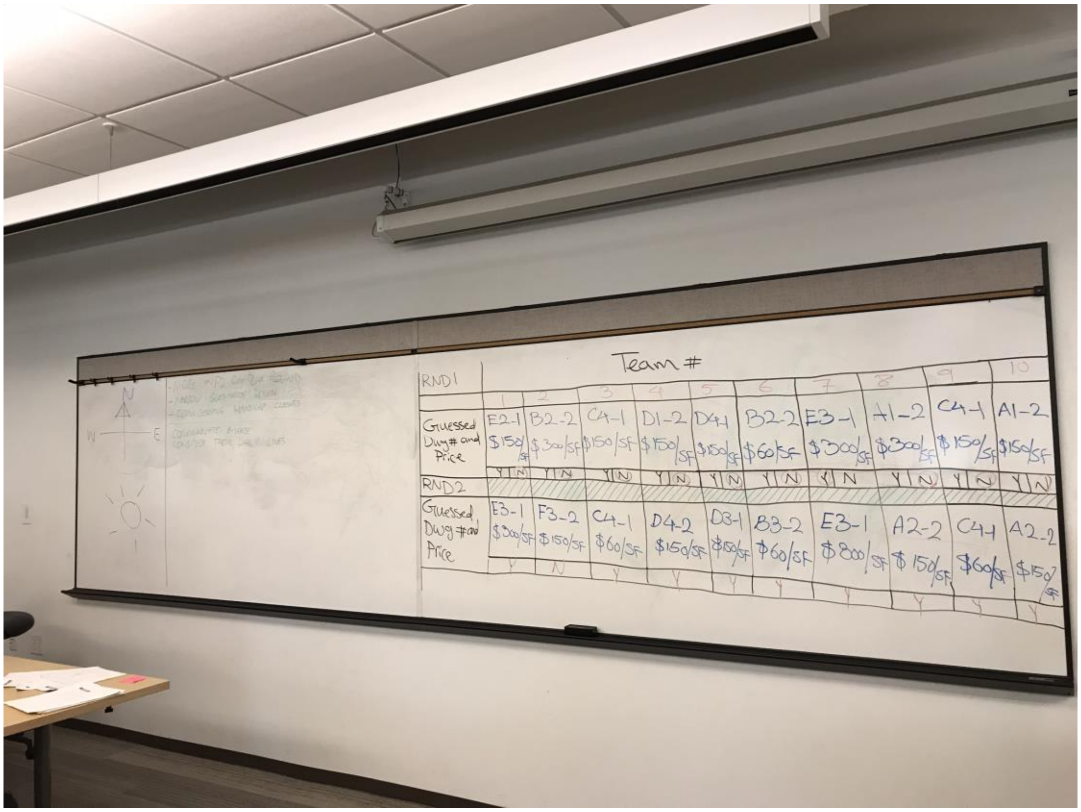


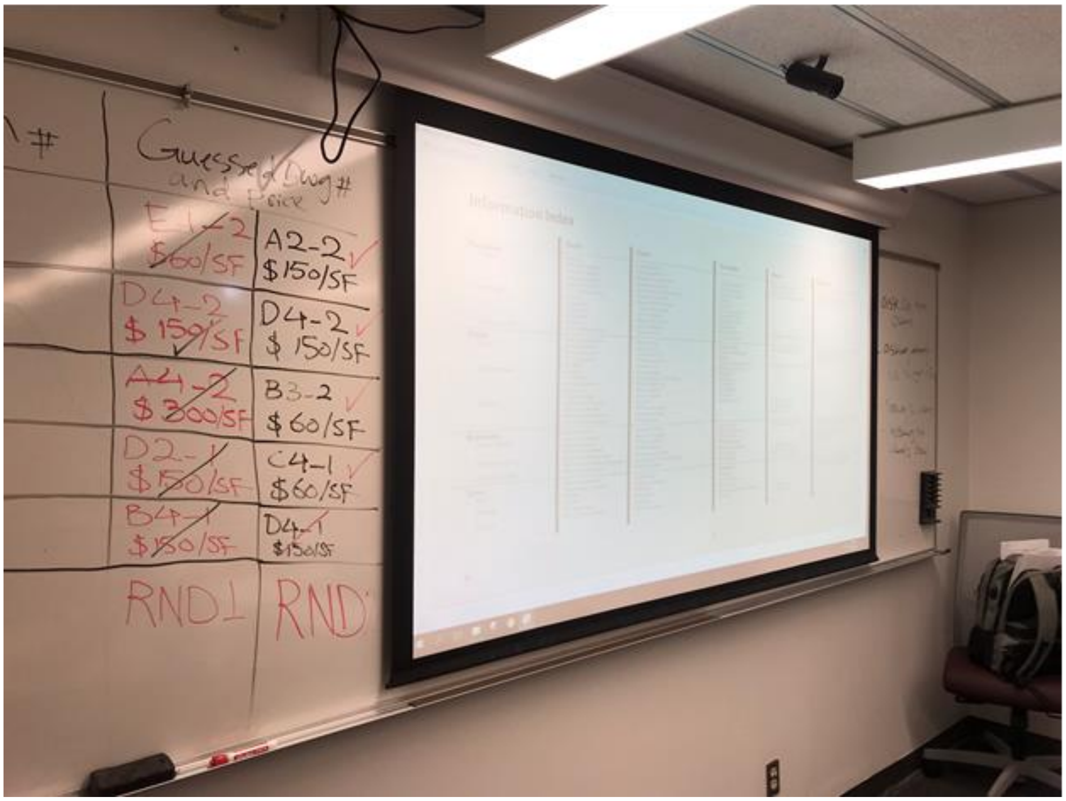





Information Index
Function
People
Activities
Relationships
Form
Site
Environment
Quality
Economy
Initial Budget
Operating Costs
Lifecycle Costs
Time
Past
Present
Future
Goals
Mission
Maximum number
Individual identity
Interaction/privacy
Ranking of values
Exercise of authority
Security
Progression
Segregation
Encounters
Efficiency
Information exchange
Bias on site elements
Sound structure
Efficient land use
Physical comfort
Life safety
Sociality
Individuality
Encoded direction
Direct entry
Projected image
Building quality level
Spatial quality level
Technical quality level
Functional quality level
Extent of funds
Cost effectiveness
Maximum return
Return on investment
Minimize operating costs
Maintenance and operating costs
Reduce life cycle costs
Historic preservation
Static/dynamic activities
Change
Growth
Occupancy date
Cost controlled growth
Facts
Statistical data
Area parameters
Manpower/workloads
User characteristics
Community characteristics
Authority structure
Value of potential loss
Time-motion study
Traffic analysis
Behavioral patterns
Space adequacy
Type/intensity
Site analysis
Soil analysis
F.A.R. and G.A.C.
Climate analysis
Code survey
Surroundings
Psychological implications
Point of reference
Entry symbols
Generic nature
Cost/S.F.
Building efficiency
Equipment costs
Area per unit
Cost parameters
Maximum budget
Time-use factors
Market analysis
Energy source-costs
Activities and climate factors
Economic data
Significance
Space parameters
Activities
Projections
Durations
Escalation factors
Concepts
Needs
Problem




Team #
RND1
Guessed Dwg # and Price
E2-1 $150/SF
B2-2 $300/SF
C4-1 $150/SF
D1-2 $150/SF
D4-1 $150/SF
B2-2 $60/SF
E3-1 $300/SF
A1-2 $300/SF
C4-1 $150/SF
A1-2 $150/SF
RND2
Guessed Dwg # and Price
E3-1 $300/SF
F3-2 $150/SF
C4-1 $60/SF
D4-2 $150/SF
D3-1 $150/SF
B3-2 $60/SF
E3-1 $800/SF
A2-2 $150/SF
C4-1 $60/SF
A2-2 $150/SF


Guessed Dwg # and Price
E1-2 $60/SF
A2-2 $150/SF
D4-2 $150/SF
D4-2 $150/SF
A4-2 $300/SF
B3-2 $60/SF
D2-1 $150/SF
C4-1 $60/SF
B4-1 $150/SF
D4-1 $150/SF
RND1
RND


Dylan Allen